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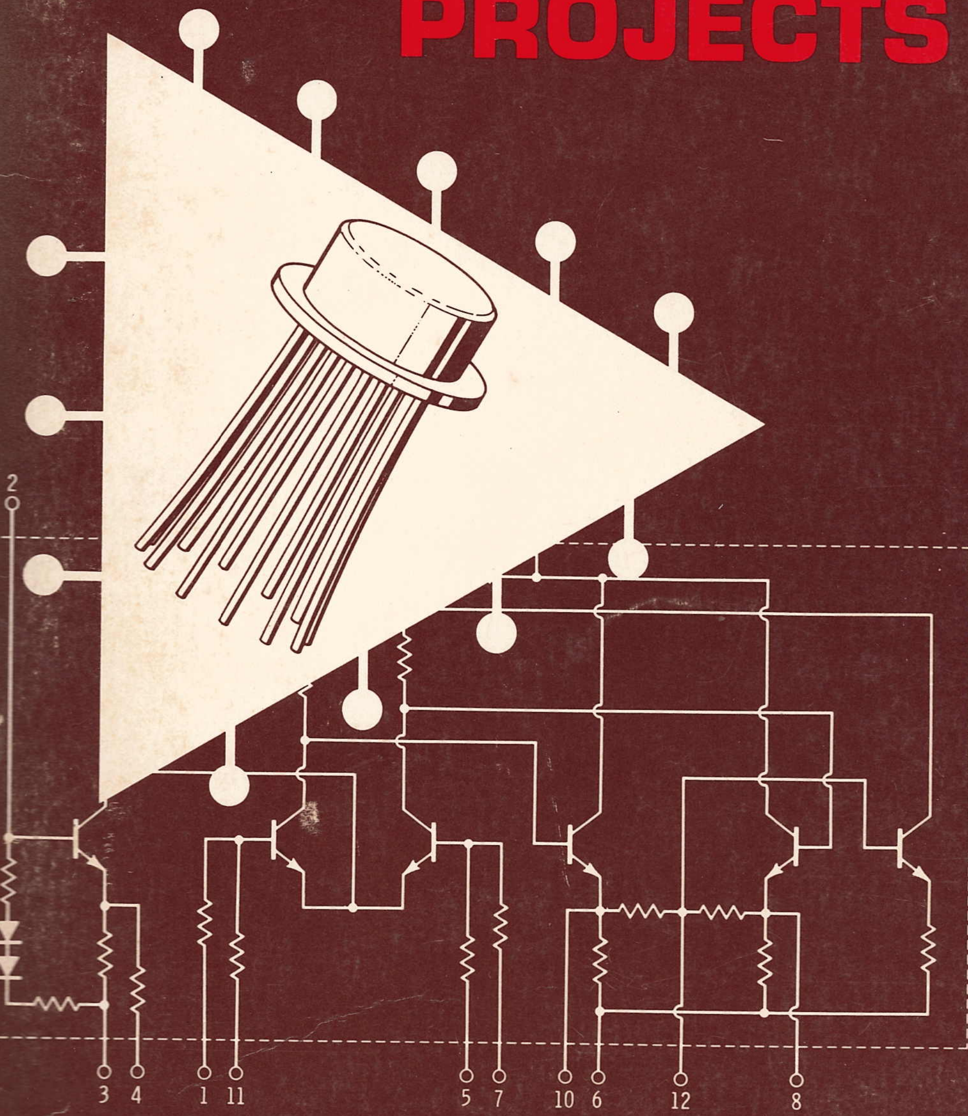
introduction to INTEGRATED CIRCUITS & IC PROJECTS



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Introduction to INTEGRATED CIRCUITS & IC PROJECTS

by

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PREFACE

There is widespread interest by hobbyists and experimenters in integrated-circuit projects. High-performance integrated circuits which can be used in audio-frequency, radio-frequency, and high-frequency (short-wave) projects are now available. It is the purpose of this book to explain practical construction projects in these areas using the latest types of integrated circuits. Each project has been planned for simplicity and efficiency. That is, printed circuits have been avoided, the most practical hardware has been chosen in each layout, and battery operation has been utilized throughout.

The first chapter provides a practical introduction to integrated circuits and explains their basic requirements. Next, the construction of an integrated-circuit audio preamplifier is explained in detail. This is a foundation unit which can be used with the subsequent projects. It can be used as a baby minder, as a one-way intercom, in a portable phonograph, or in a public-address (pa) unit. Chapter 3 explains the construction of an a-m tuner that can be used with the previous amplifier. This is basically a high-fidelity tuner. It provides fine reception on local a-m broadcast stations, provided that the preamplifier is connected to a hi-fi speaker.

An rf/if signal tracer is described in Chapter 4. When used with the preamplifier, it is useful in troubleshooting radio and tv receivers. The signal tracer can also be used to check the output from a signal generator, to monitor the output from a Citizens band (CB) transmitter, to make transmitter neutralizing adjustments, and can be adapted for operation as a relative field-strength meter. Chapter 5 explains various audio-

oscillator applications using the preamplifier as the basic unit. These applications include a code-practice oscillator, light-dependent audio alarm, fire alarm, and a darkness-responsive audio alarm.

Chapter 6 explains the construction of an integrated-circuit audio amplifier, which can be used with the previous amplifier in a high-gain audio system or with the a-m tuner. A pair of these amplifiers can be utilized in a simple stereo system. Chapter 7 explains the construction of an integrated-circuit tuner. This tuner has considerably greater sensitivity than the simple tuner discussed previously. A sensitive tuner is particularly advantageous in remote areas where field strengths are comparatively weak.

The last chapter explains the construction of an integrated-circuit high-frequency tuner, with a frequency coverage from 9 to 27 MHz. It provides an entry into the world of short-wave reception. Depending upon atmospheric conditions and the season of the year, this tuner provides reception over extremely great distances. It can be used with the preamplifier or with both the preamplifier and output amplifier.

ROBERT G. MIDDLETON

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CHAPTER 1

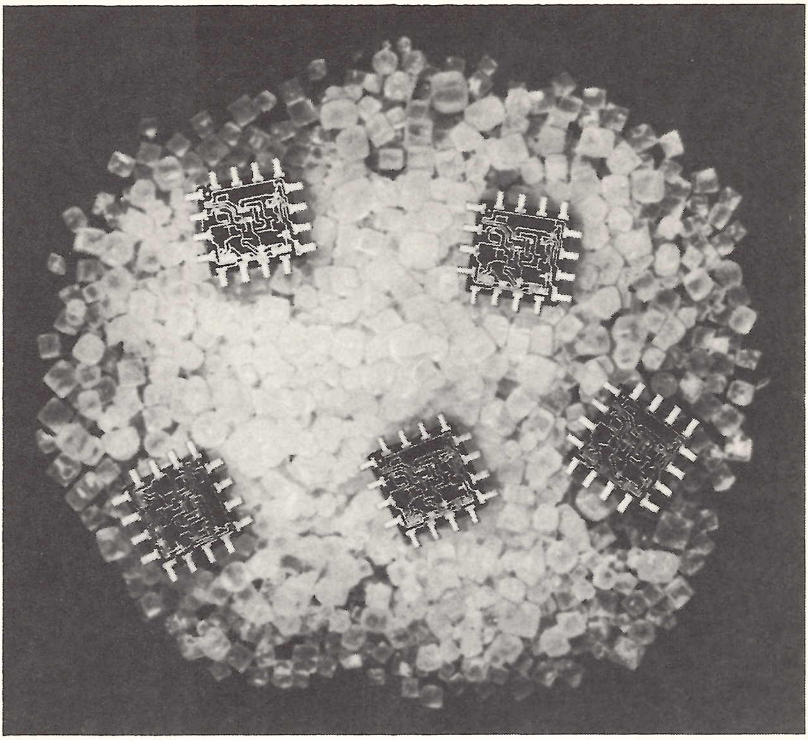
GENERAL CONSIDERATIONS

Integrated circuits (ICs) are miniaturized solid-state devices (Fig. 1-1) that perform the operations of several transistors. The IC has found applications in all kinds of electronic equipment ranging from radios and televisions to space vehicles. Because of the small size of the integrated circuits, they can now be plugged in and out of electronic equipment in the same manner as a single transistor.

In many respects the IC can be considered as a refined and subminiature version of the electronic module. The first modules used tubes and were considerably large as compared to the transistor circuits of today. Printed-circuit techniques accounted for size reduction and improved quality. Finally this gave way to the IC. An integrated circuit no larger than a transistor can contain a number of diodes, transistors, resistors, capacitors plus all of the connections among these various components. The various input and output connections are made at points in the tiny circuit and brought out to pigtails and lugs for external connections.

Some integrated circuits look like large transistors. For example, a TO-5 IC package and matching socket are depicted in Fig. 1-2. In many cases, a socket is not used and the IC terminal leads are soldered directly onto the board. An IC surrounded by all the parts it replaces is indicated in Fig. 1-3.

We will also find dual in-line IC packages, flat-packs, and staggered-lead arrangements, as exemplified in Fig. 1-4.



Courtesy Motorola Semiconductor Products, Inc.

Fig. 1-1. Comparing the size of an IC to salt crystals.

Sockets may be employed with the dual in-line IC packages, although it is generally preferred to solder the IC terminal leads directly into the external circuit. Regardless of its shape or terminal arrangement, an IC amplifier package is usually symbolized by a triangle, as seen in Fig. 1-5. In this example, terminal 1 is the input signal point and terminal 8 is the output signal point. That is, the symbol implies amplifier action through the package from left to right.

The price of an IC can be kept down when assembly and encapsulation is done on a large scale. Their packages are designed to keep costs at a minimum by adaptability, easy soldering, and minimum use of board space. Fig. 1-6 illustrates the finished IC as compared to IC units that come right off the assembly line.

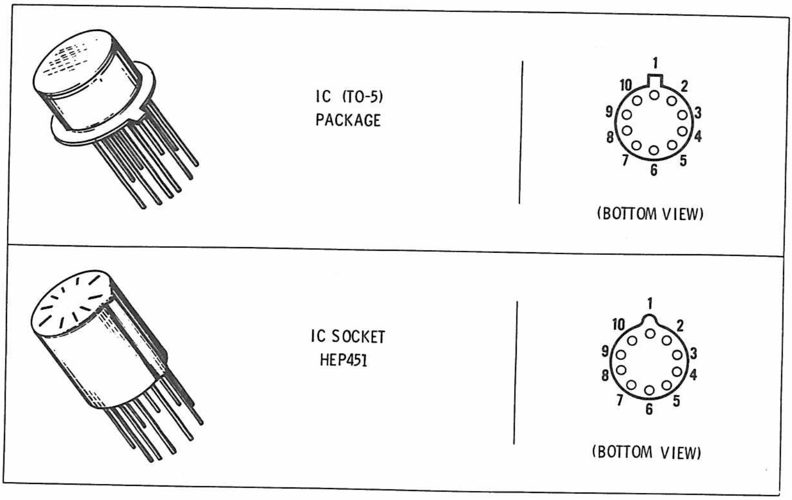


Fig. 1-2. A TO-5 IC package and matching socket.

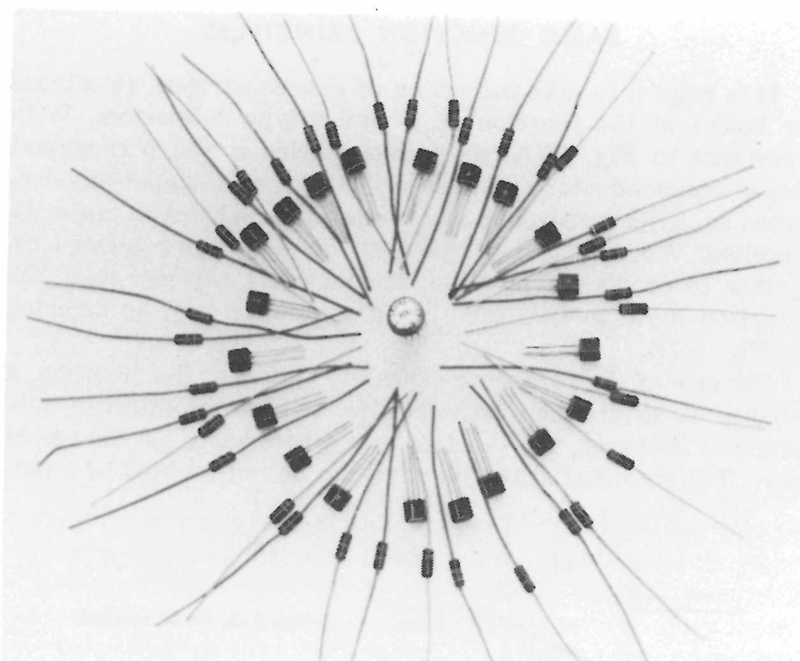
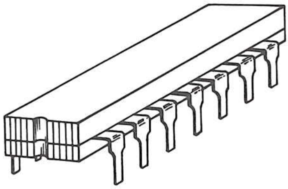
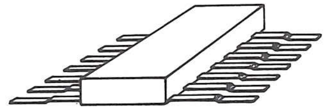


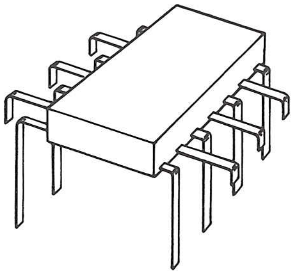
Fig. 1-3. An IC surrounded by the components it replaces.



(*A*) *Dual in-line.*



(*B*) *Flat-pack.*



(*C*) *Staggered-lead.*

Fig. 1-4. Types of IC packages.

BASIC JUNCTION PRINCIPLES

It is helpful to note the action of charge carriers (electrons or holes) at the junction of p- and n-type substances. With reference to Fig. 1-7A, the blocks labeled n and p represent doped semiconductor substances. The n-type substance has electrons as majority carriers and the p-type has holes as majority carriers. When p- and n-type semiconductors are formed together to produce a junction, the majority carriers near the junction move toward each other and cancel out, as depicted in Fig. 1-7B.

Because of the foregoing canceling action at the junction, a charge is established between the two semiconductor substances. However, the junction as a whole has a net charge of zero. The potential at the junction can be represented by a bat-

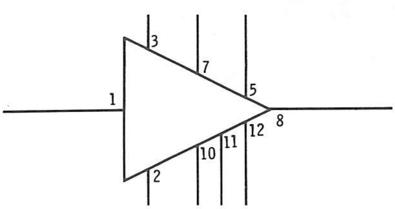
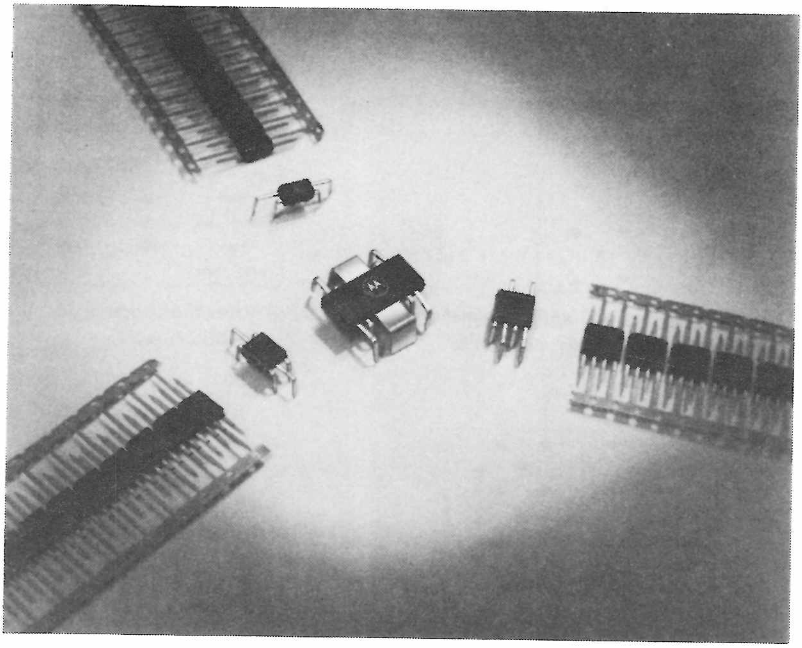


Fig. 1-5. An IC symbol.

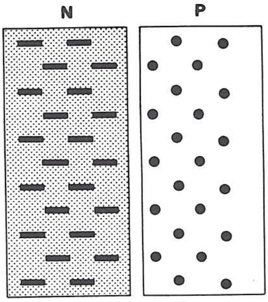


Courtesy Motorola Semiconductor Products, Inc.

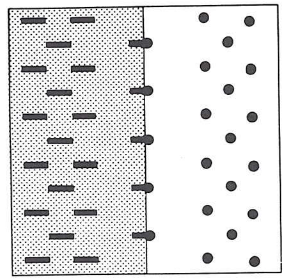
Fig. 1-6. Finished IC compared to units just off the assembly line.

tery in Fig. 1-7C. It is only a few tenths of a volt, but it has a basic function in that it represents a potential barrier that must be overcome for electrons or holes to pass from one side of the junction to the other. This barrier potential can be increased or decreased by the application of an external voltage.

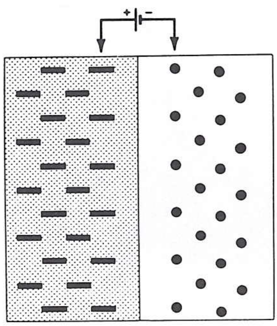
We will find that a pn junction operates as a one-way valve or rectifier to current flow. Current flowing in the forward or low-resistance direction is called *forward* bias. On the other hand, current flowing (or attempting to flow) in the high-resistance direction is called *reverse* bias. The potential barrier at the pn (or np) junction, represented by the battery in Fig. 1-7C, must be overcome before current can flow. When an external battery is connected so that it aids the potential hill (increases its value), the carriers are pulled further away from the junction, as shown in Fig. 1-8. The negative terminal of the battery attracts the holes to the right, and the positive terminal attracts the electrons to the left. Such a reverse-biased junction can have a resistance value measured in



(*A*) *Two types of semiconductor materials and their carriers.*



(*B*) *Action that occurs at a junction.*



(*C*) *Battery designating polarity of charge at the junction.*

Fig. 1-7. Action of carriers at a junction.

megohms. The more that a junction is reverse-biased, the greater its resistance becomes.

The forward biasing of a junction reduces the potential barrier. That is, the carriers are moved up to the junctions as

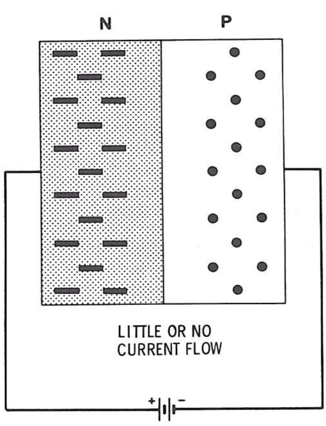


Fig. 1-8. Result of connecting a battery to aid the potential hill (reverse biasing).

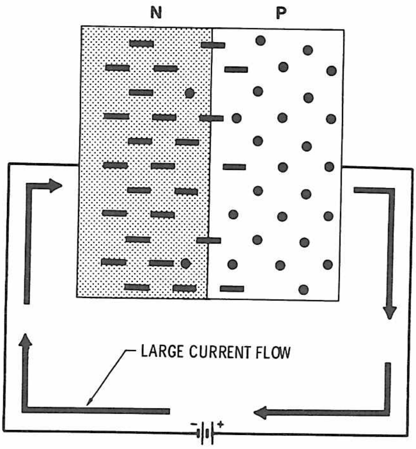


Fig. 1-9. Result of connecting a battery to reduce the potential hill (forward biasing).

depicted in Fig. 1-9. Holes and electrons now flow across the junction, and there is a current flow in the external circuit. We may state that the battery injects excess holes into the p-type substance by removing electrons and injects excess electrons into the n-type substance. Forward bias differs from reverse bias in that the necessary forward potential to overcome the potential barrier is comparatively small. Once the potential barrier is removed, there is little opposition to current flow. As the forward bias increases, the junction resistance decreases. Of course, the semiconductor substance has some resistance but this is quite small. That is, a small increase in forward voltage will produce a very large increase in forward current.

A transistor consists of an emitter (E), a base (B), and a collector (C), as shown in Fig. 1-10. This arrangement is for an npn transistor. Correct base-to-emitter bias polarity for an

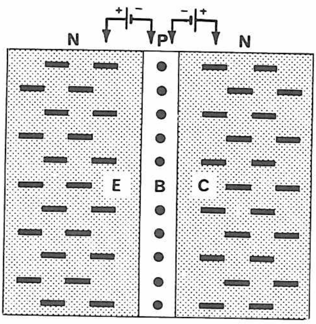
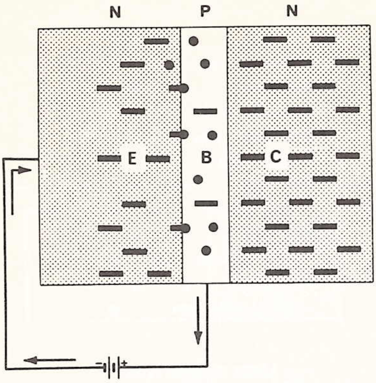
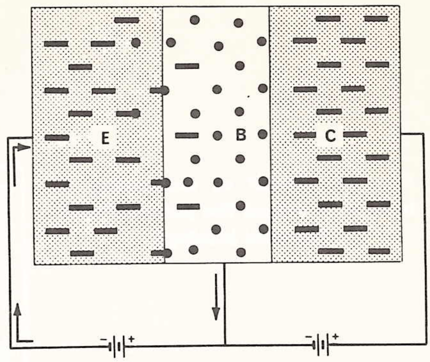


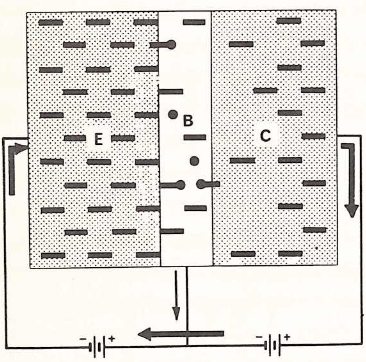
Fig. 1-10. Arrangement of an npn transistor.



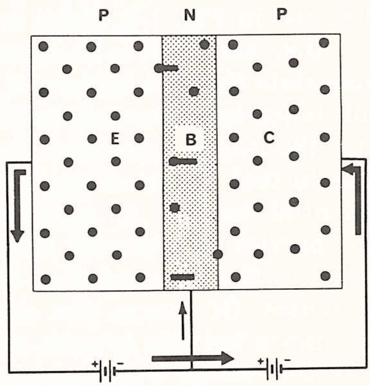
(*A*) *Proper bias for an npn transistor.*



(*B*) *Action caused by connecting a second battery in the reverse-bias direction of an npn transistor.*



(*C*) *Effect of thin base region on transistor action.*



(*D*) *A pnp transistor showing reverse action.*

Fig. 1-11. The effect of forward and reverse biasing.

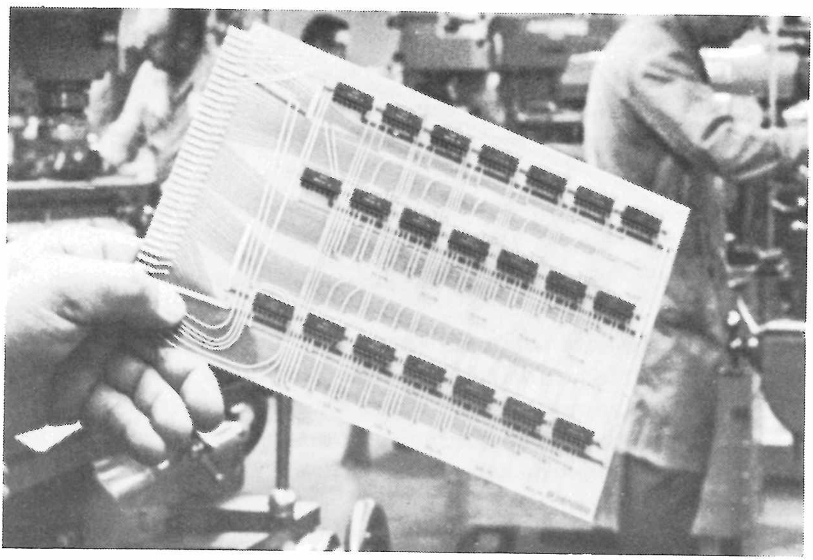
npn transistor is seen in Fig. 1-11A. The majority carriers are forced up to the junction, and a current flow takes place between base and emitter. Holes move into the n-type substance, and electrons move into the p-type substance. Recombination takes place at the junction, and can also take place after carriers may have passed the barrier. The existence of minority carriers (electrons in this example) in the base region is of major importance to transistor operation.

When free electrons exist in the emitter region of an npn transistor, they are majority carriers. On the other hand, when these same electrons cross the junction into the base region,

they are minority carriers. These electrons eventually combine with holes in the base region. In Fig. 1-11B a second battery is connected to the transistor. It produces a reverse bias, and causes the carriers to move away from the base-to-collector junction. A wide base region permits all of the electrons from the emitter to recombine with holes in the base region. However, in Fig. 1-11C the base region is shown thin, as in actual practice. Electrons forced into the base region by forward bias at the emitter-to-base junction are now attracted by the positive charge of the n-type substance at the junction of the collector and base. A large number of electrons now traverse the base region and reach the collector before recombination takes place. Because of the greater voltage operating in the collector circuit, the transistor amplifies. Fig. 1-11D illustrates the reverse action of a pnp transistor.

INTEGRATED-CIRCUIT THEORY

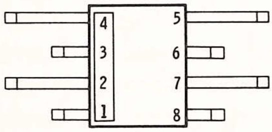
It is helpful to understand how integrated circuits work. As noted previously, integrated circuits are integral solid-state units that contain transistors and associated components such



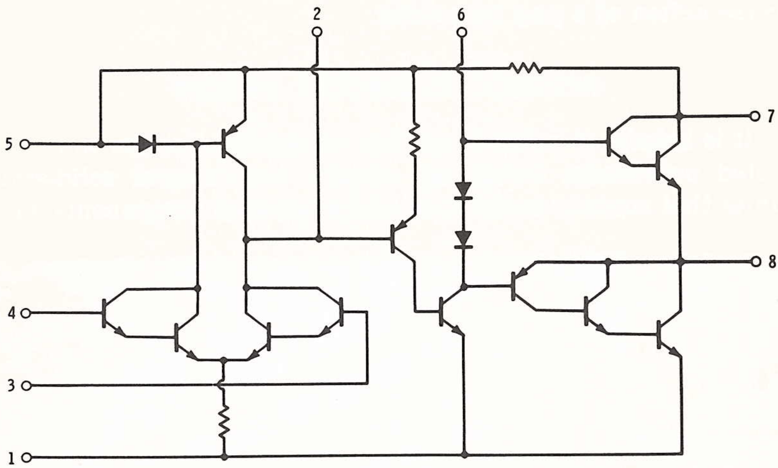
Courtesy Motorola Semiconductor Products, Inc.

Fig. 1-12. Integrated logic circuits.

as resistors, diodes, and sometimes capacitors. Their small size allows several ICs to be installed upon a single card (Fig. 1-12). However, the simplest integrated circuits may contain only a few transistors. On the other hand, a large-scale integrated circuit may contain dozens of transistors, resistors, diodes, and capacitors. Fig. 1-13 shows a moderately elaborate integrated circuit and its internal circuitry. If it were fabricated with individual components, 12 transistors, three diodes, and three resistors would be utilized, as illustrated in Fig. 1-14.



(A) Appearance of package (top view).



(B) Internal circuitry.

Fig. 1-13. An IC and its internal circuitry.

The components in an integrated circuit are formed simultaneously during fabrication. This technique may introduce factors that are not present when a circuit is wired with separate components. For example, two transistors may be employed to perform the same function as a single separate transistor in a conventional circuit. Nevertheless, the two equivalent transistors would occupy far less space than the single individual transistor in a conventional circuit. Transistors in an integrated circuit are similar to ordinary transistors, except

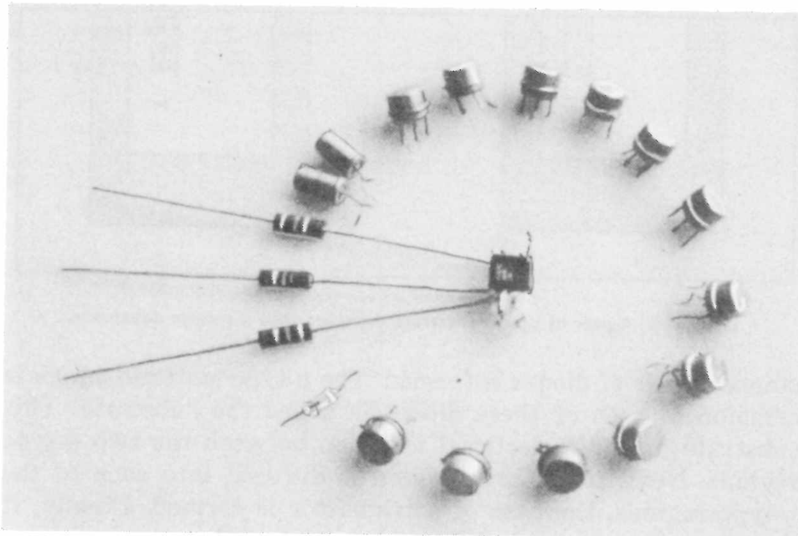


Fig. 1-14. IC surrounded by its equivalent individual components.

that more distributed capacitance may be involved due to the compact construction.

Resistors used in an integrated circuit are basically constructed of semiconductor material and are, accordingly, more temperature dependent than conventional composition resistors. Therefore, we find that integrated circuits are designed on the basis of resistance ratios rather than absolute resistance values. In other words, the tolerance on an integrated resistor is greater than the usual tolerance on a composition resistor. This dependence on resistance ratios is a fundamental reason for using more than one transistor in a stage. Therefore, the design of stable integrated circuits is accomplished although the resistance values of the internal circuitry tend to drift with changes in temperature.

The stability of an integrated circuit in the presence of temperature changes is also based on the fact that since the internal resistors are contained in the same chip, the percentage of resistance drift is practically the same for each resistor. A typical integrated circuit is fabricated from a silicon wafer of a p-type substance. In turn, most all of the transistors in an integrated circuit are of the npn type. If a pair of n-type regions are diffused at separate places into the p-type sub-

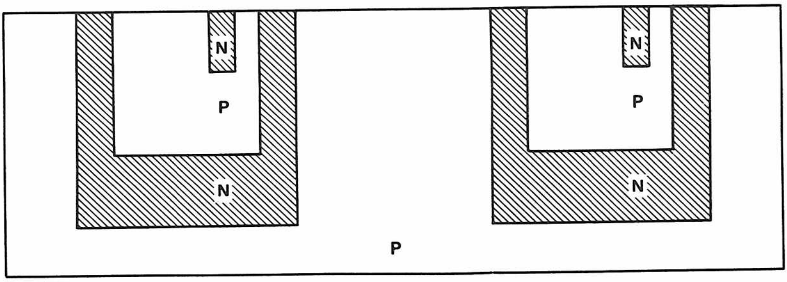


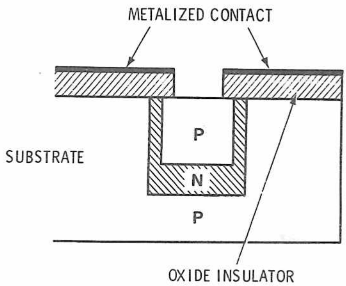
Fig. 1-15. A pair of npn transistors diffused into a p-type substrate.

stance, a pair of diodes is formed. The p-type material which is common to both of these diodes is called the substrate. This substrate provides electrical isolation between the two n-type regions. Next, if a p-type region is diffused into each of the n-type regions, the base of a transistor is formed. Finally, if another n-type region is diffused into each of the p-type regions, a pair of transistors is formed, diagrammed in Fig. 1-15. Note that the p-type substrate provides electrical isolation between the two transistors. Metallized contacts are made to the electrodes of the transistors.

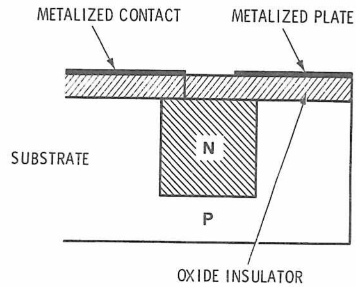
In Fig. 1-15, note that the upper n-type regions are emitters, the interwoven p-type material forms the bases, and the lower n-type regions are the collectors. When a resistor is to be fabricated in the chip, the upper n-type region in Fig. 1-15 is not used. Instead, two separate contacts are made to the p-type substance. The amount of resistance provided by this p-type substance depends entirely on its length, width, and depth. The lower n-type regions serve to provide electrical isolation between the p-type resistor and the substrate. When capacitors are to be formed, only the initial n-type region is used. An oxide layer is utilized as the dielectric of the capacitor. Plans for an integrated resistor and an integrated capacitor are depicted in Fig. 1-16. Compare Fig. 1-16 to the typical resistors and capacitors that are illustrated in Figs. 1-17 and 1-18 respectively.

INTEGRATED-CIRCUIT FABRICATION

Integrated-circuit fabrication starts with wafers consisting of silicon squares or circles about 0.01 inch thick, and perhaps



(*A*) *Resistor.*



(*B*) *Capacitor.*

Fig. 1-16. How integrated resistors and capacitors are formed.

2 inches in diameter. Each wafer yields from 250 to 1000 IC chips, each from 0.015 to 0.1 inch square (Fig. 1-19).

Fig. 1-20 illustrates how a typical IC is fabricated. A wafer is highly polished to a mirror surface in the first step of manu-

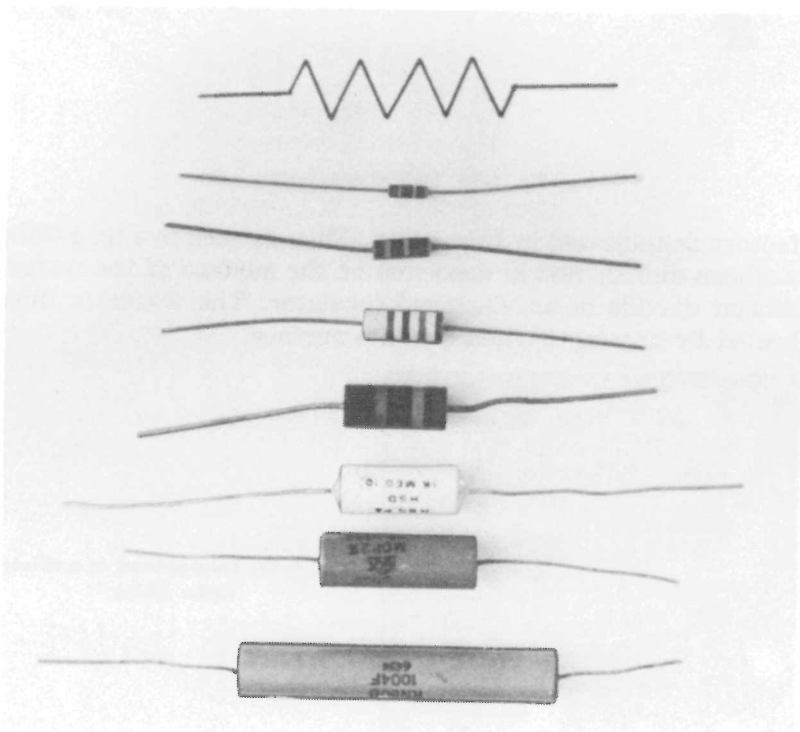


Fig. 1-17. Typical resistors.

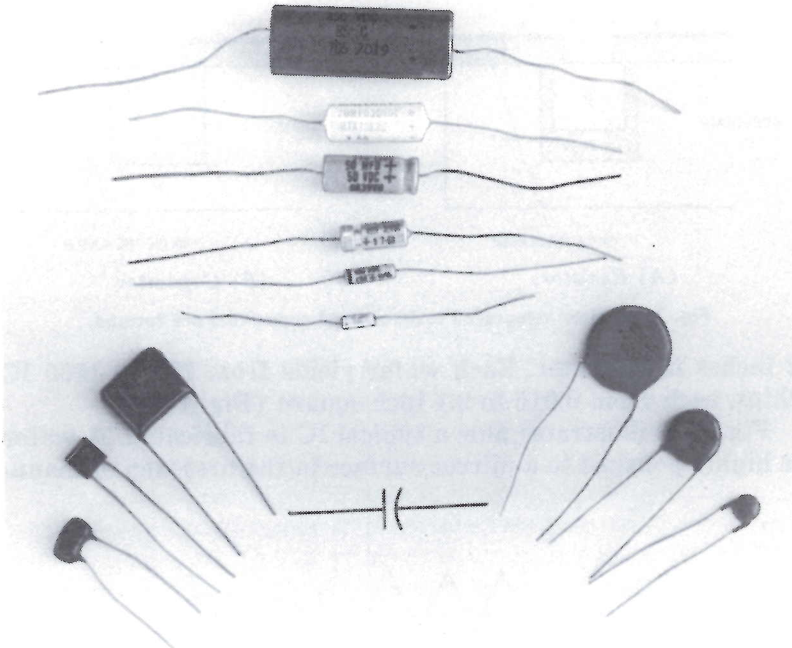
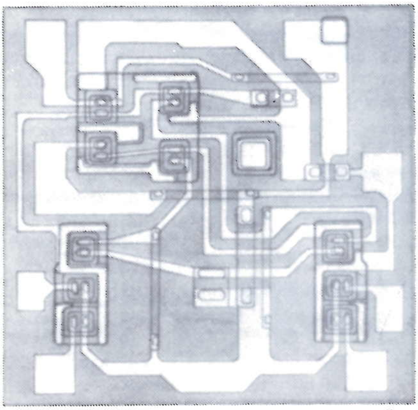


Fig. 1-18. Typical capacitors.

facture as indicated in Fig. 1-20A. Then as seen in Fig. 1-20B, a silicon-dioxide film is deposited on the surface of the wafer. Silicon dioxide is an electrical insulator. The wafer is then heated by passing oxygen over its surface.



Courtesy Motorola Semiconductor Products, Inc.

Fig. 1-19. Enlargement of a silicon wafer (chip).

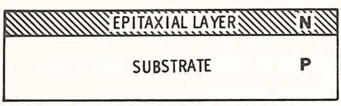
The next step in IC fabrication involves the formation of openings or windows at the required points in the silicon-dioxide film. An opening might be as small as 0.0001 inch square. Photochemical processes and masks are utilized to form windows in each chip, with simultaneous processing of up to 1000 chips. A photomask is a glass plate with tiny black spots that prevent the passage of light at certain places. In Fig. 1-20C, the photochemical film on the silicon dioxide is hardened by exposure to light but remains soft under the black spots. These soft portions are removed by a "developing" process after which the wafer is etched by strong acid. As indicated in Fig. 1-20D, this acid dissolves the silicon dioxide in the window areas but does not dissolve the n-type silicon epitaxial layer beneath the silicon dioxide.

After cleaning, the wafer is placed in an electric furnace for doping with suitable chemical vapors in a diffusion process. In Fig. 1-20E, vapors are used to produce p-type regions in the wafer. Of course, several sequential diffusion procedures are required as illustrated by Figs. 1-20F, G, H, and I. As noted previously, these diffusion processes result in the formation of transistors, resistors, diodes, and capacitors. It is impractical to form inductors in a wafer, and capacitors are limited to comparatively small values. After the active (transistor) and passive (diode, resistor, and capacitor) components have been formed in the wafer, metallic connecting leads are fabricated. This entails the use of aluminum vapor. The aluminum forms the interconnecting wires of the circuit.

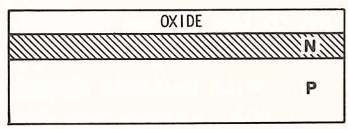
Before the wafer is processed further, precise electrical testing procedures are required. There is always a certain amount of waste due to random defects in fabrication. Numerous needle-tipped probes are employed to make test contacts with the aluminum conductors on each chip. This is done automatically, and a wafer might require several thousand electrical measurements to locate defective chips. The chips are cut from the wafer by means of a diamond cutter, after which they are sorted to weed out the defective chips. This often involves inspection of chips under a microscope. Finally, chips that pass final inspection are packaged and electrical tests are made on the finished units. These operations are automated to minimize production costs so the finished product can be purchased at a reasonable price.

IC OPERATION

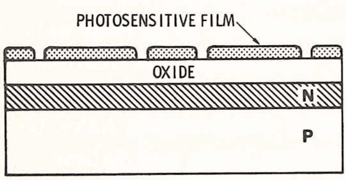
Let us consider the operation of the integrated circuitry depicted in Fig. 1-21. Transistor Q1 is in the common-emitter configuration, and the input signal is applied to its base. Next, we observe that Q1 drives Q2 and Q3, which operate in the common-base configuration. This arrangement is often called a cascode pair, or a common-emitter/common-base configuration. Basically, a cascode circuit employs a pair of transistors connected in series with each other. This arrangement reduces feedback from output to input and exploits the advantages of both the common-emitter and common-base operating modes to



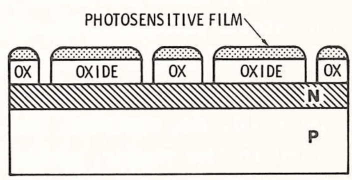
(A) Monolithic fabrication starting material.



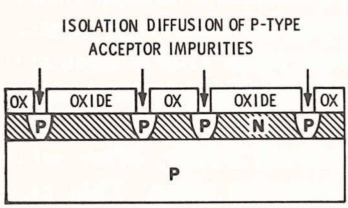
(B) First step is oxidation of the silicon wafer.



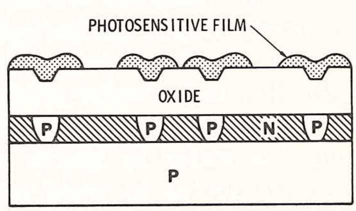
(C) A photosensitive film is applied, exposed, and developed on the oxide surface (using a mask to determine the pattern).



(D) Oxide not covered by the photosensitive film is etched away.



(E) Impurity atoms are diffused into the oxide layer.

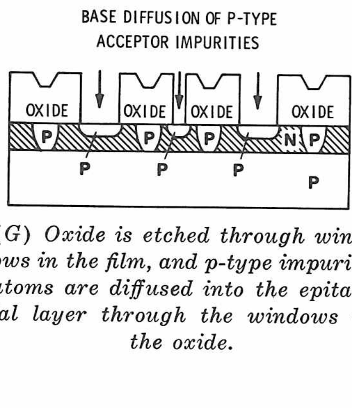


(F) Additional oxide is grown, a photosensitive film is applied, exposed, and developed (using a mask to determine the pattern).

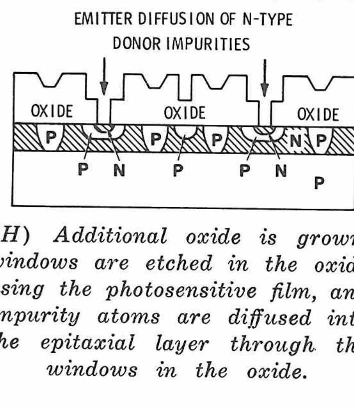
Fig. 1-20. The monolithic

obtain stability over a substantial temperature range. Note that Q2 and Q3 do not operate in push-pull. That is, the collector of Q3 is at signal ground (decoupled by the power supply) and the signal output is taken from the collector of Q2. Dc coupling is used throughout, as in most integrated-circuit packages.

Note that agc (automatic gain control) is employed in the application depicted in Fig. 1-21. Automatic gain control is used to maintain the output volume of a receiver at a constant level. In case the i-f stage in Fig. 1-21 is to be operated at maximum gain at all times, the agc lead is connected to the 20-volt supply lead. This is the way that we will utilize this integrated circuit in a subsequent construction project. Diode D1 is provided for delayed agc operation, if desired. Resistors R1 and R2 are used to bias the base of Q2 and to bias D1. Resistors R3 and R4 are utilized to spread the agc dynamic range for noise reduction when agc is employed. The emitter current in Q1 diffuses first into the collector of Q1 and next into the emitters of Q2 and Q3. With the agc lead connected to the supply-voltage lead, Q2 operates at maximum gain, and Q3 is cut off. On the other hand, if the agc lead were open, Q2

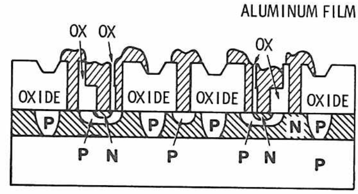


(G) Oxide is etched through windows in the film, and p-type impurity atoms are diffused into the epitaxial layer through the windows in the oxide.



(H) Additional oxide is grown, windows are etched in the oxide using the photosensitive film, and impurity atoms are diffused into the epitaxial layer through the windows in the oxide.

(I) An aluminum film is evaporated everywhere on the surface and selectively removed to create contacts to the semiconductor areas and to the interconnecting wires. (A photosensitive film and an etchant are used to achieve this.)



fabrication process.

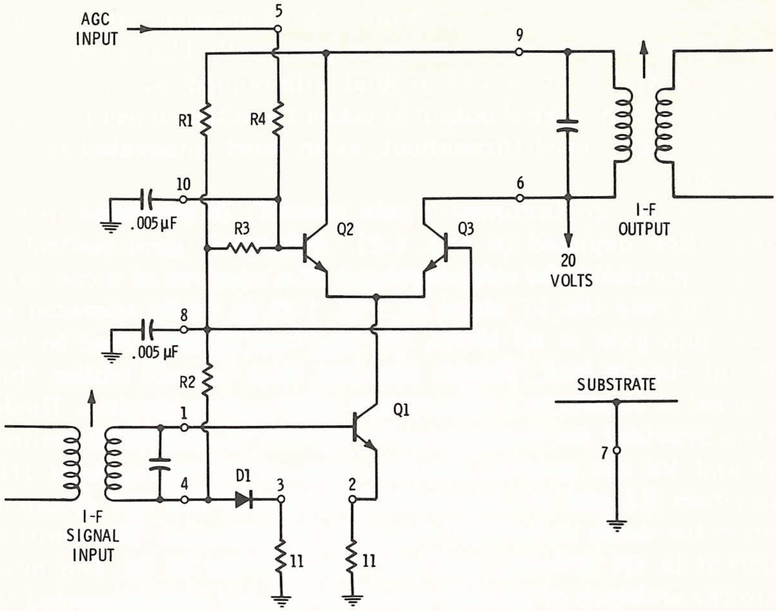


Fig. 1-21. Integrated i-f circuit with external components.

would be nearly biased off, and Q3 would be biased into conduction. Therefore, the stage gain would be very low under this operating condition.

We observe that the integrated circuit depicted in Fig. 1-22 develops gain through transistors Q1 and Q2, which are connected in cascode. That is, Q3 serves as a stabilizing device. Collector current from Q1 divides between Q2 and Q3. When the IC is operating at maximum gain, Q3 is cut off, and all of the collector current from Q1 flows into Q2. On the other hand, when the IC is operating at minimum gain, Q2 is cut off

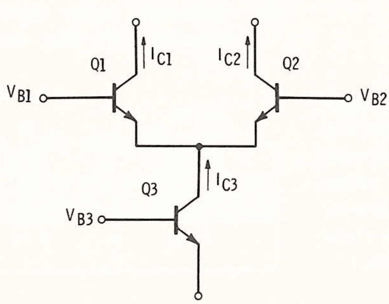


Fig. 1-22. IC employing a cascode circuit.

and all of the collector current from Q1 flows into Q3. Note that the emitter of Q2 is effectively grounded, and that signal output is taken from the collector of Q2. The emitter current for Q1 flows through an 11-ohm emitter degeneration resistor. This degeneration assists in obtaining stable operation over a substantial range of temperature.

With reference to Fig. 1-22, transistors Q1 and Q2 are often said to operate in a differential amplifier configuration. This is basically an emitter-coupled push-pull amplifier arrangement, in which transistor Q3 serves as a common-emitter resistor. A transistor is employed as the common-emitter resistor in this arrangement because the transistor provides a comparatively constant-current source which assists in obtaining temperature stability. Note that a push-pull signal can be applied to the bases of Q1 and Q2, and an amplified push-pull signal will be obtained from the collectors of Q1 and Q2. Or, as is more common in simple applications, the base of Q2 would be effectively grounded, and a single-ended signal would be applied to the base of Q1. In turn, due to differential amplifier action, a push-pull amplified signal would be obtained from the collectors of Q1 and Q2.

Of course, the base of Q1 could be effectively grounded in Fig. 1-22, and a single-ended signal applied to the base of Q2. In turn, an amplified push-pull signal would be obtained from the collectors of Q1 and Q2. Since Q3 operates practically as a constant-current device, the sum of the collector currents that flow through Q1 and Q2 remains essentially constant. This means that if Q1 draws less emitter current, then Q2 must draw more emitter current. Or, if Q2 draws more emitter current, then Q1 must draw less emitter current. This is why phase inversion occurs in the collector circuits of Q1 and Q2 even though only one of the transistors is driven by an input signal. Note that if we change the base voltage on Q3, the constant-current value will be changed accordingly.

Returning now to Fig. 1-21, we perceive that when Q1 is driven by the input signal, the result is a change in the value of current that is made available to Q2 and Q3. With Q3 cut off, all of this current flows into the emitter of Q2 and is amplified in the common-base mode. Therefore, an amplified signal appears at the collector of Q2. The input signal has effectively been amplified through a common-emitter stage and then

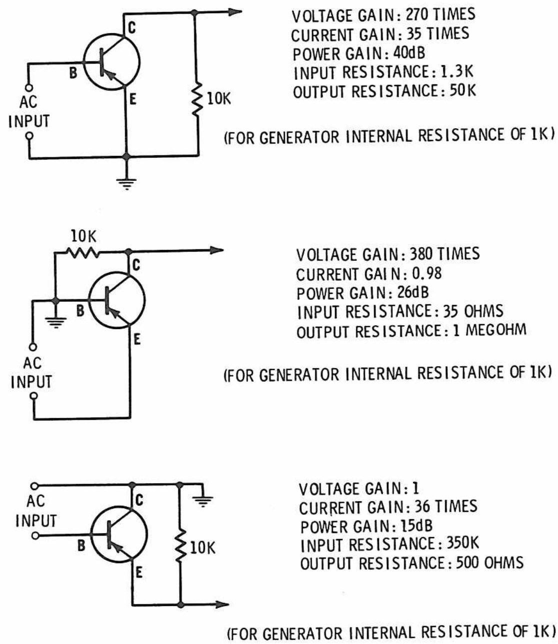


Fig. 1-23. Summarizing basic transistor facts.

through a common-base stage. It is apparent that there is nothing mysterious about IC operation and that ordinary transistor theory applies throughout. Fig. 1-23 summarizes the basic operating facts that are involved in signal analysis.

BASIC CLASSIFICATIONS OF INTEGRATED CIRCUITS

Integrated circuits in general can be classified into logic and linear types. However, this distinction is not necessarily sharp, inasmuch as a logic IC might be utilized as a linear IC, or vice versa. ICs in logic applications perform switching functions as in digital computers. On the other hand, ICs in linear applications operate basically as amplifiers. In this book, we are concerned only with linear operation of integrated circuits. Typical subclassifications of linear ICs are: audio preamplifier, ¼-watt audio amplifier, 1-watt audio amplifier and preamplifier, 2-watt audio amplifier and preamplifier, 4-watt audio amplifier, wideband amplifier, stereo preamplifier, chroma demodulator, i-f amplifier with agc, wideband i-f limiter, de-

tector, audio preamplifier and driver, four-stage high-gain fm/if amplifier, i-f amplifier with quadrature detector, fm/if amplifier, limiter, detector, audio driver, and electronic attenuator, class-A audio driver, high-frequency amplifier, wideband amplifier/discriminator, and fm multiplex stereo demodulator.

Integrated-circuit catalogs and manuals may provide an extensive characterization of individual integrated circuits, or only a bare minimum of specifications may be provided. The catalog generally provides a reference section on case styles. Somewhat more elaborate IC catalogs show the internal circuit of the device. Cross-references may also be provided. Note that such cross-references do not necessarily designate exact replacements.

CHAPTER 2

CONSTRUCTION HINTS

When constructing any kind of project, one must think ahead, be deliberate, and know in advance what is coming. This is what makes this chapter so important. The tools used in fabricating the IC projects must be the correct type to be used in that situation. A good knowledge of soldering, supply-voltage sources, mounting sockets, grounding, IC ratings, actual construction, component tolerances, and battery connections should be obtained.

Careful studying of this chapter will enable an individual to have a working knowledge in these areas so that he may progress to the actual IC project construction with confidence.

TOOLS AND SUPPLIES

Before starting an IC construction project, the following tools and supplies (Fig. 2-1) should be obtained:

1. Soldering iron (preferably a pencil type).
2. Needle-nose pliers.
3. Small diagonal cutter.
4. Assorted small screwdrivers.
5. Hand drill and assorted bits.
6. Vom or tvm.
7. Hacksaw.
8. Rosin-core solder.

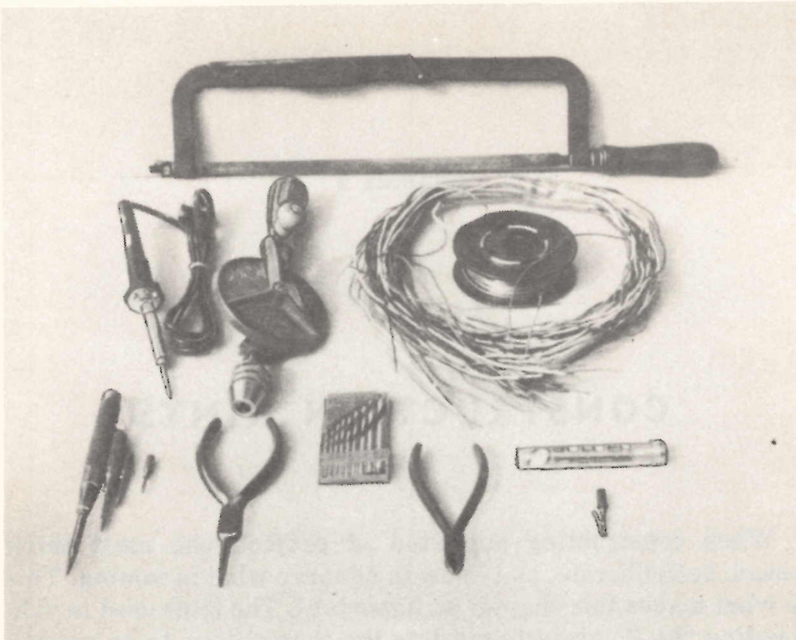


Fig. 2-1. Tools and supplies used in IC construction projects.

9. Insulated hookup wire and No. 22 bare copper wire.
10. A small file and household cement are optional.

It is also desirable to have an assortment of machine screws, nuts, washers, and lugs available.

SOLDERING TECHNIQUES

Careful soldering is essential in IC construction work. The following principles of good practice are important, and should be observed:

1. Use rosin-core solder only.
2. Whenever it is practical, make a good mechanical joint before soldering a connection.
3. Any insulation or tarnish must be cleaned from surfaces to be soldered.
4. The surfaces must be adequately heated for the solder to flow, but avoid excessive heating.

5. Allow a few seconds for the solder to harden before moving any part of the joint.
6. Never solder to an IC, transistor, or diode terminal without first attaching a heat sink to protect the semiconductor.

MOUNTING SOCKETS

A TO-5 IC socket has a diameter of $\frac{3}{8}$ inch. If a socket is used in a construction project, the following procedure will be found helpful. It is assumed that a perforated board is to be utilized. First, drill a $\frac{3}{8}$-inch hole at the mounting location in the perforated (perf) board. The socket will fit too tightly at this time, and the hole should be reamed slightly to provide a snug fit. Then, use a small file to notch the board for the ridge on the IC socket. Place the notch at a point 180° from where pin No. 1 is to appear (Fig. 2-2). This will permit the socket to be locked in final position. With a small file, cut a $\frac{3}{32}$-inch notch in the IC socket ridge as shown in Fig. 2-3. The socket may then be inserted and locked in position by rotating it 180°. Finally, the socket can be firmly secured in place by a drop or two of household cement.

SUPPLY-VOLTAGE SOURCES

Either a battery or power-supply voltage source can be utilized. Nine-volt radio batteries are suggested in the following construction projects. If there is a need to operate an amplifier continuously for a long period of time, lantern-type batteries will meet the requirement. If a power supply is used,

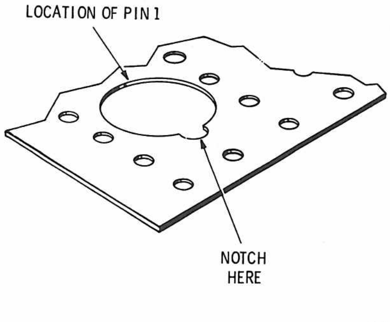


Fig. 2-2. Preparation of perf board for mounting an IC socket.

it must be well filtered. Note that the audio-freqeuncy amplifiers described in the following chapters employ large electrolytic capacitors across the supply-voltage terminals. A large bypass capacitor ensures stable operation, particularly when batteries are no longer new. When a preamplifier is used to drive an output amplifier, for example, it is good practice to operate each amplifier from a separate battery. Otherwise, instability may be encountered.

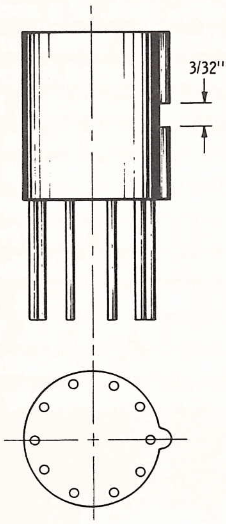


Fig. 2-3. Notching the IC socket ridge.

GROUNDING CONSIDERATIONS

In most cases, an earth or water-pipe ground will not be required. However, when high-gain systems are installed, unstable operation may sometimes occur which can be controlled only by connecting the preamplifier ground terminal to a water pipe. Note that input and output components often have floating metal housings which can cause instability unless these metal structures are connected to the amplifier ground terminal. For example, metal speaker housings should be connected to the ground terminal of the associated amplifier. Metal battery cases should also be connected to the ground terminal. Of course, input and output cables or devices should be kept widely separated, to avoid feedback.

INTEGRATED-CIRCUIT RATINGS

Integrated circuits are rated for power-supply voltage, gain, power output, input impedance, output impedance, percentage distortion, current drain, and noise rejection. We must be careful not to exceed the recommended power-supply voltage, or the IC is likely to be damaged. Some ICs are rated for only 8 volts, while others are rated as high as 33 volts. It is also essential to observe proper voltage polarity. It is important to note that the rated power output cannot be obtained unless the rated supply voltage is employed. If the supply voltage is considerably subnormal, distorted output may result even at low-output levels.

Most ICs have comparatively high gain. For example, a single IC can provide the complete audio system in a radio or television receiver. That is, an IC may replace two or three conventional transistors. The size comparison between conventional transistors and diodes to integrated circuits is illustrated in Fig. 2-4. Input and output impedances of ICs are

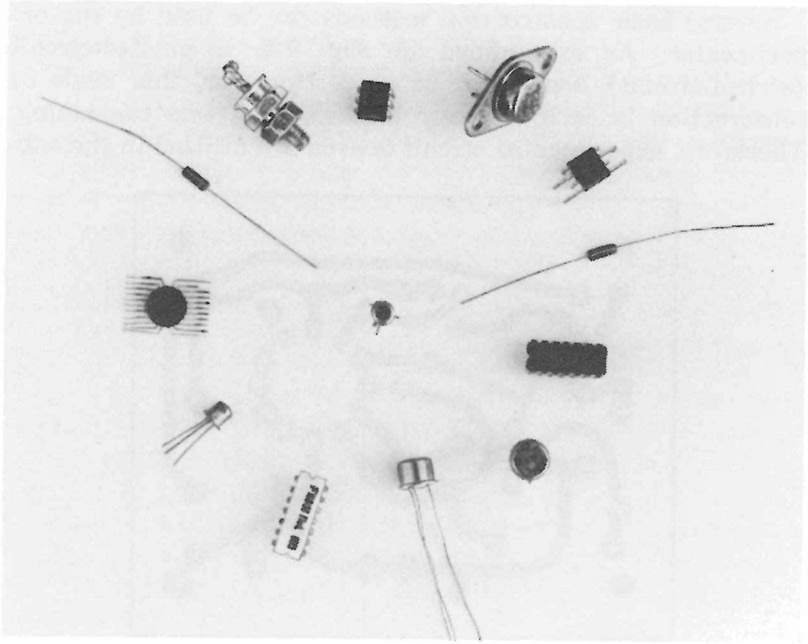


Fig. 2-4. Comparing an IC to conventional diodes and transistors.

generally comparable to those of conventional transistor amplifiers. Since many ICs are rated for output impedances as low as 16 ohms and as high as 100 ohms, they can drive speakers directly, without the use of output transformers. This mode of operation provides optimum fidelity since most of the distortion would otherwise be imposed by the output transformer. An IC may develop as little as 0.1% distortion. It is also characterized by a low noise level and conservative current drain.

Integrated circuits are also rated for frequency response. Some ICs are suitable for audio-frequency applications only, while others have full response up to 60 MHz. In general, audio-frequency ICs are rated for higher gain and higher power output than high-frequency ICs. For example, an audio IC might be rated for 90-dB (decibel) gain and 4-watts output, whereas a high-frequency IC may be rated for 26-dB gain and 680-milliwatts output. Of course, the audio IC would have zero gain and zero output if it were used in a 60-MHz circuit.

BASIC PROJECT CONSTRUCTION

Several basic construction methods can be used by the experimenter. As exemplified in Fig. 2-5, a printed-circuit (etched-circuit) board can be used. However, this mode of construction is comparatively difficult and time consuming. Therefore, experimenter circuit boards are utilized in the sub-

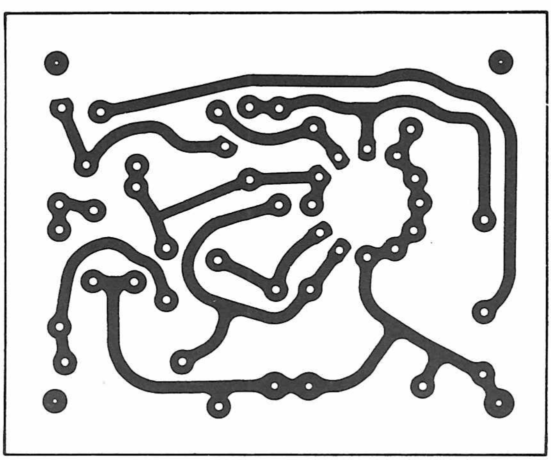


Fig. 2-5. Typical printed-circuit board.

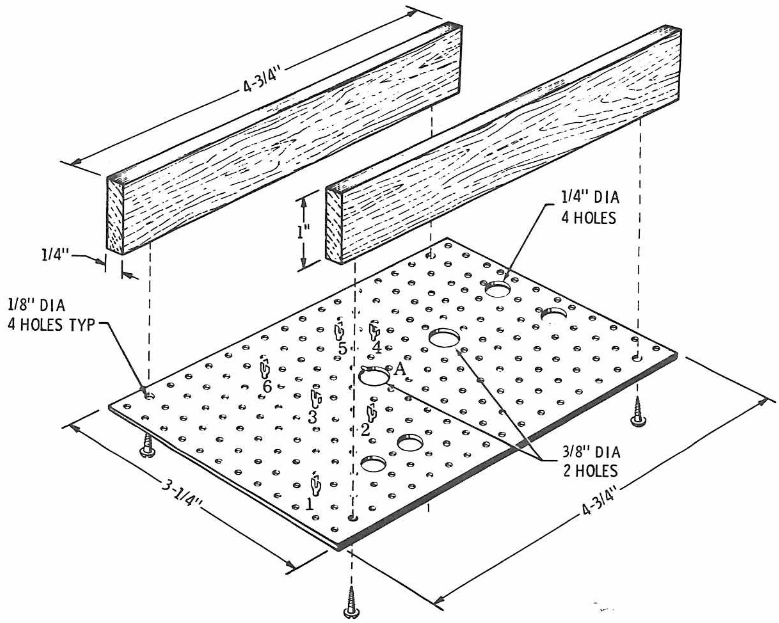


Fig. 2-6. Typical perf board with supports.

sequent projects. Note that if you feel ambitious, a printed-circuit layout can be developed for each of the projects. On the other hand, the same performance will be obtained from the simpler construction methods that are suggested and used in this book.

Perf boards provide maximum convenience for the experimenter. A perf board has numerous small holes (Fig. 2-6) which are designed to pass component leads or push-in terminals. The two wood blocks in Fig. 2-6 can be used to support the perf board. If you wish to minimize construction time, skip the push-in terminals and simply pass component leads through the various holes in the perf board. It also saves time to pass the IC terminal lugs through holes in the perf board, instead of installing an IC socket.

Perf boards are also available with a copper surface on the underside. They are convenient for making up printed circuits. In addition, the copper surface can be used as a ground plane and partial shield in high-gain IC projects wherein operating stability might otherwise be a problem. We will use copper-clad perf boards in some of the subsequent IC projects for this

reason. Each project has been planned for easy construction and efficient operation.

COMPONENT TOLERANCES

All electronic components and devices such as integrated circuits have production tolerances. Some ICs have fairly wide tolerances. Resistors used in the subsequent projects have a suggested tolerance of 10%. You will find that some resistor values (those that determine bias voltages) may be somewhat critical. Therefore, if you experiment with a "spread" of resistance values, you will sometimes improve the operation of an IC unit considerably. For example, suppose that you find that an amplifier or a tuner works better at reduced supply voltage. This means that one or more of the bias resistors has a value that is not optimum. Therefore, it is advisable to operate the unit at the rated supply voltage, and to change the values of the bias resistors up or down as required to obtain peak performance. Thereby, full sensitivity and full power output will be obtained.

BATTERY CONNECTIONS

When an IC project is battery-powered, it is usually necessary to connect two or three batteries in series to obtain the rated value of supply voltage. For example, two 9-volt transistor radio batteries may be connected in series to obtain an 18-volt supply. Again, three 9-volt radio batteries may be con-

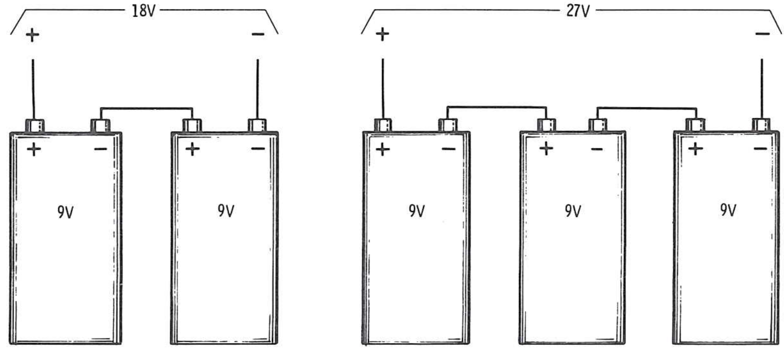


Fig. 2-7. Principle of series battery connections.

nected in series to obtain a 27-volt supply. Or, a 6-volt lantern battery may be connected in series with a 12-volt lantern battery to obtain an 18-volt supply. One 6-volt and two 12-volt lantern batteries connected in series will provide a 30-volt supply. Fig. 2-7 shows the principle of series battery connections.

CHAPTER 3

INTEGRATED-CIRCUIT AUDIO PREAMPLIFIER

This project contains the construction of an integrated-circuit audio preamplifier with a gain of 90 dB. The complete project is illustrated in Fig. 3-1. Since this amplifier can provide an output of 1 watt, it can be used to operate a speaker directly, if desired. A pair of these amplifiers can be utilized in a stereo system. It can also be used, for example, in a portable phonograph or a public-address unit.

CIRCUIT DESCRIPTION

A Motorola HEP C6002 integrated circuit is utilized in this project. The IC is ¼ inch square and has eight terminals. Its terminal arrangement is depicted in Fig. 3-2A. Although we are not concerned practically with the internal configuration of the IC, it is interesting to note the internal circuitry shown in Fig. 3-2B. An IC socket is not utilized in this project, and solder connections are made directly to the IC terminals.

Fig. 3-3 shows the configuration of the preamplifier. An off-on switch was not included, as it is easy to snap the battery clip off when the amplifier is not in use. However, if you prefer, you can use a volume control with an off-on switch to disconnect the battery. In any case, since the IC draws approximately 8 mA, the battery should not be left connected to the amplifier when it is not being used. Note that the metal housing of the

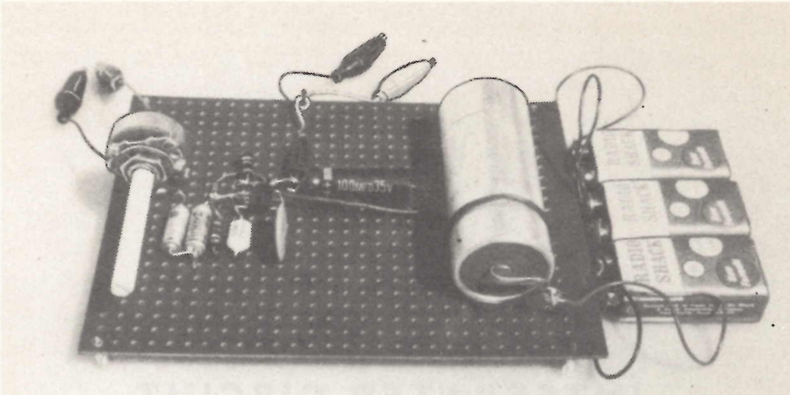
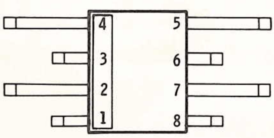


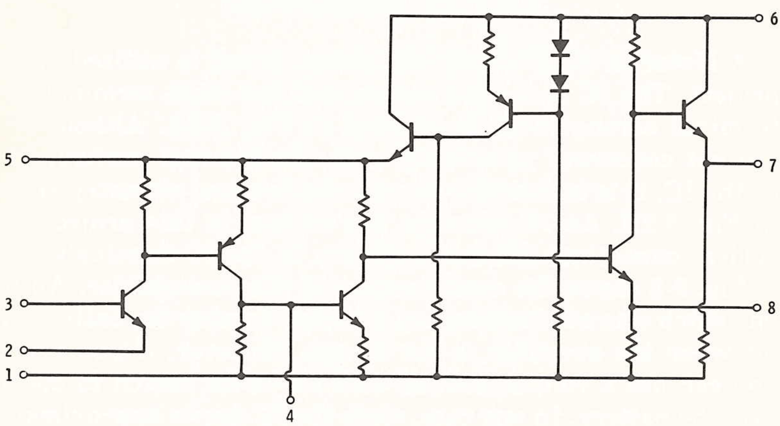
Fig. 3-1. Completed IC audio preamplifier project.

potentiometer is grounded to avoid the possibility of unstable operation and/or hum pickup.

It is desirable to employ a copper-clad perf board in this project to avoid possible instability. This preamplifier need not be installed in a metal box unless it is to be operated in a high-



(A) Terminal arrangement.



(B) Internal circuitry.

Fig. 3-2. The C6002 integrated circuit.

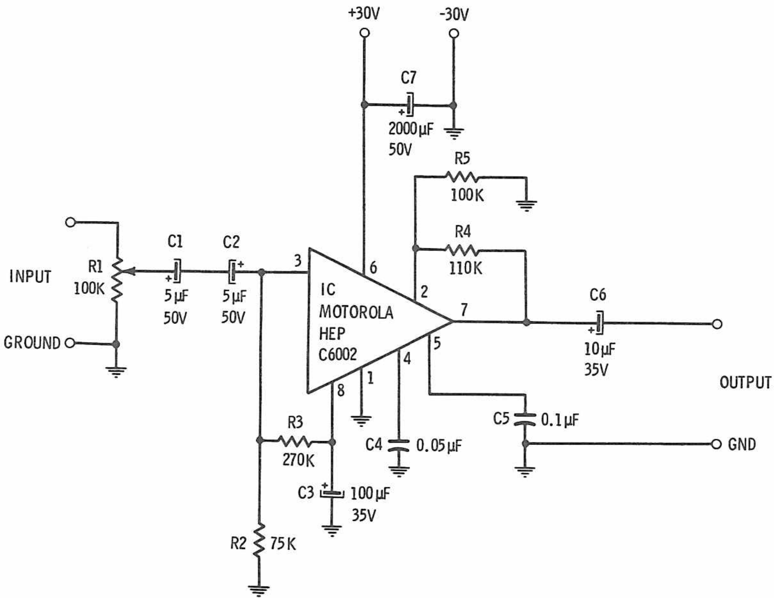


Fig. 3-3. Preamplifier configuration.

noise location. For example, if you operate the unit in the vicinity of fluorescent lamps, it is likely to pick up considerable noise unless it is enclosed in a metal box. The external circuitry is indicated in Fig. 3-3. All parts are indicated in Table 3-1. Fig. 3-4 shows the appearance of the preamplifier with speakers. Note that two 40-ohm speakers are connected in series to supply an 80-ohm load for the amplifier. Thereby, the necessity for an output transformer is avoided, and optimum fidelity is obtained.

Before proceeding to mount the parts on the perf board, check all component values carefully. An off-value resistor, for example, could cause trouble symptoms, or even damage the IC. Fig. 3-5 shows the parts layout, with a pictorial wiring diagram corresponding to Fig. 3-3. Note that the IC is mounted bottom-up in Fig. 3-5. This facilitates connections to the IC terminal lugs. Observe the IC terminal numbers in Fig. 3-5. These correspond to the numbers shown in Fig. 3-2. Be careful not to reverse the IC end-for-end when mounting it on the perf board. As shown in Fig. 3-2, terminals 1,2,3, and 4 are located along the left side of the IC.

Table 3-1. Parts List for IC Audio Preamplifier

Item	Description
C1, C2	Capacitors, 5 microfarad, 50 volt, electrolytic
C3	Capacitor, 100 microfarad, 35 volt, electrolytic
C4	Cpacitor, 0.05 microfarad, tubular
C5	Capacitor, 0.1 microfarad, ceramic disc
C6	Capacitor, 10 microfarad, 35 volt, electrolytic
C7	Capacitor, 2000 microfarad, 50 volt, electrolytic
IC	Integrated circuit, Motorola HEP C6002
R1	Potentiometer, 100,000 ohm, 1/2 watt, linear taper
R2	Resistor, 75,000 ohm, 1/2 watt, 10%
R3	Resistor, 270,000 ohm, 1/2 watt, 10%
R4	Resistor, 110,000 ohm, 1/2 watt, 10%
R5	Resistor, 100 ohm, 1/2 watt, 10%
Circuit board	Perforated board, copper-clad
Speakers	40-ohm voice coil (2)
Batteries	9-volt transistor type (3)
Test cords	With insulated clips (2)
Battery clips	For 9-volt battery

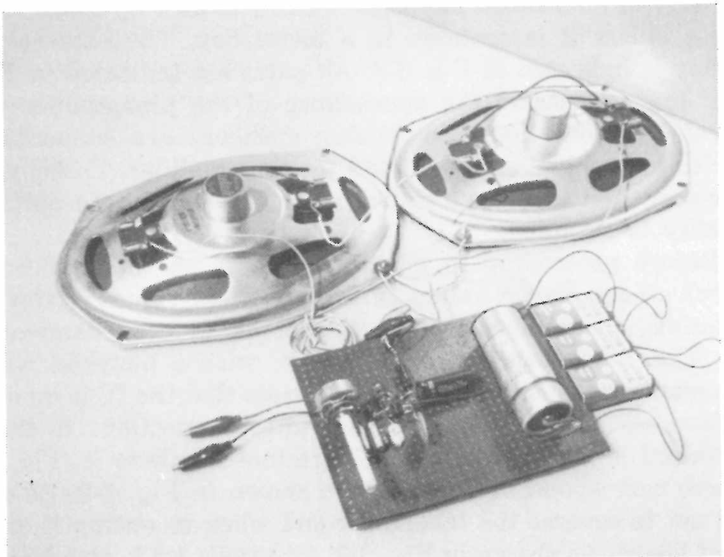


Fig. 3-4. Preamplifier with speakers.

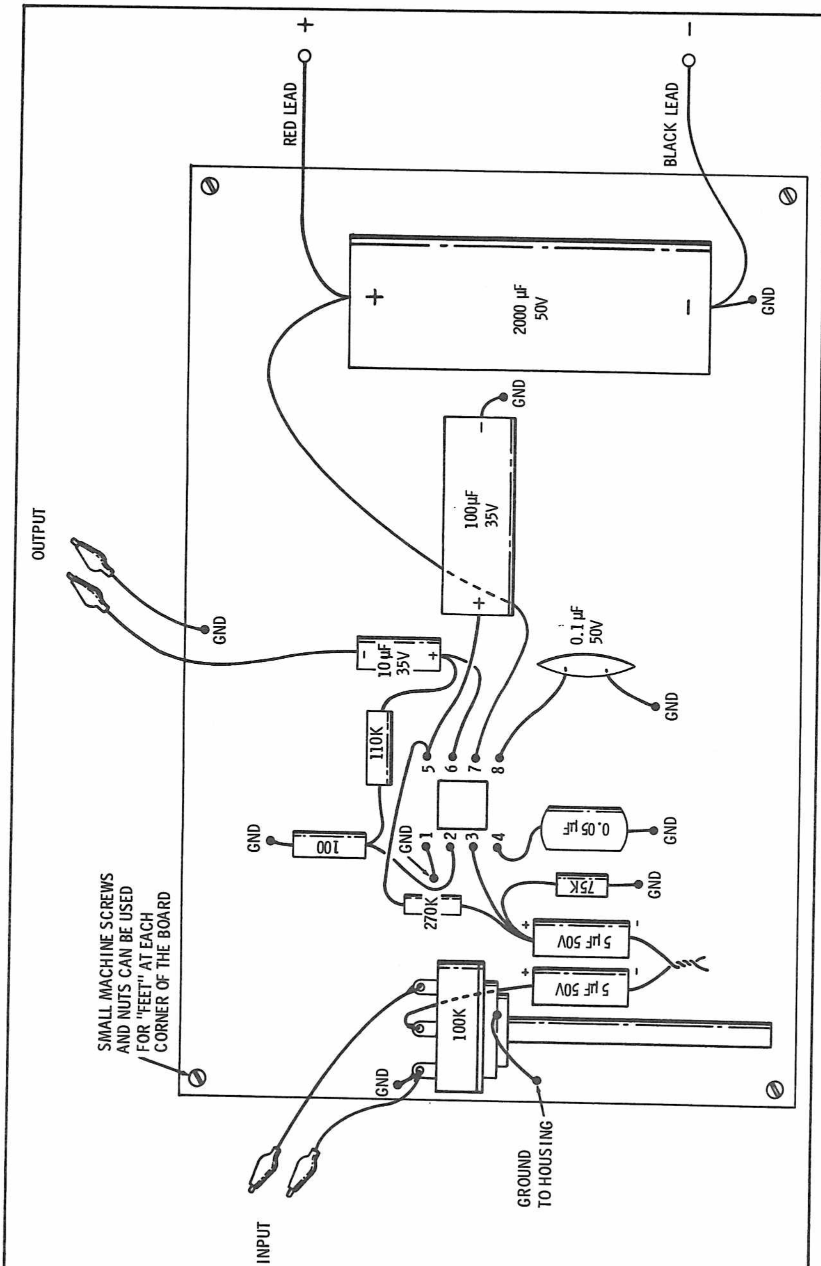


Fig. 3-5. Parts layout and wiring.

Since the circuit board has numerous perforations, it is a simple procedure to insert the ground leads of capacitors and resistors through various holes. The leads are clipped below the board and soldered to the copper-clad surface. If a pencil-type soldering iron does not produce enough heat to solder to the copper sheet, use an ordinary soldering gun in this part of the procedure. Note that electrolytic capacitors are polarized, and it is essential to observe correct polarity. In general, connections to the IC terminals should be made last. Also, it is very important to use a pair of thin-nose pliers (or a small alligator clip) as a heat sink as each IC terminal is soldered. Apply the heat sink between the solder joint on the terminal and the body of the IC. Allow the joint to cool before removing the heat sink.

One of the output leads (with its miniature alligator clip) is connected to the negative terminal of the 10-μF capacitor. The other output lead is connected to the copper-clad surface of the perf board. For strain relief, tie the output leads together in a square knot at the edge of the perf board. This ensures that excessive force will not be accidentally applied to the IC when speakers are connected or disconnected.

Since three 9-volt batteries are employed, one of the battery-snap strips must be cut to separate the positive and negative snaps. The snap with the red lead can be connected to the positive terminal of the 200-μF capacitor, and the snap with the black lead can be connected to the negative terminal of the 200-μF capacitor. Series connectors for the batteries are made up from similarly cut battery-snap clips. Thus, the amplifier is operated from a 27-volt source. Note that this IC has a maximum rating of 30 volts. Therefore, you can employ one 6-volt and two 12-volt lantern batteries connected in series, if you prefer. It is very important to make sure that batteries are connected up with the correct polarity.

TESTING THE AMPLIFIER

To test the completed amplifier, connect a pair of 40-ohm speakers to the output leads. Fig. 3-6 shows how to connect the speakers noted in the parts list. Turn the speakers in the same direction, and connect the terminals as shown to obtain correct impedance and proper phasing. Note that the housings of the

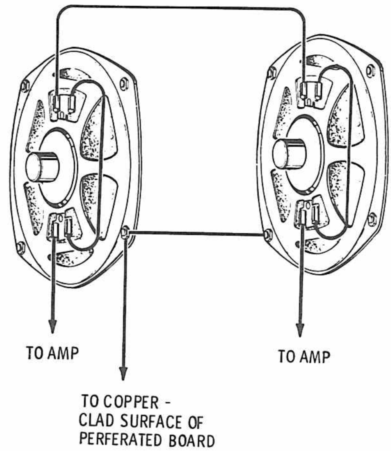


Fig. 3-6. Wiring the speaker.

speakers are connected together and to the ground plane of the amplifier. Connect the batteries to the amplifier. Now, if you turn the volume control to maximum, you will normally hear a low-level "rushing" sound from the speakers. This is thermal noise, which is present because of the high gain of the amplifier. Next, turn the volume control to zero and touch your finger to the input test clip. Advance the volume control, and you will normally hear a 60-Hz hum from the speakers.

In case the amplifier does not pass the foregoing tests, recheck the component values, connections, polarities and look for cold solder joints. If the trouble is not located, enlist the aid of a friend to make an independent check of your work. It is often helpful to get an independent point of view, because we are prone to make certain types of errors that may be overlooked repeatedly. Make sure that the batteries are supplying their rated voltage. As noted previously, it is possible to damage an IC by overheating during the wiring procedure. If a wiring error has been made, remember that the IC may have been operated out of limits and possibly damaged.

After the amplifier has passed its initial tests, a practical distortion test can be made, as depicted in Fig. 3-7. A small speaker with an output transformer is used as a microphone to drive the amplifier. When the volume control is advanced, the speakers will "howl" unless the microphone is placed some distance away. That is, acoustic feedback will occur if the microphone and speakers are in proximity. However, a cable can

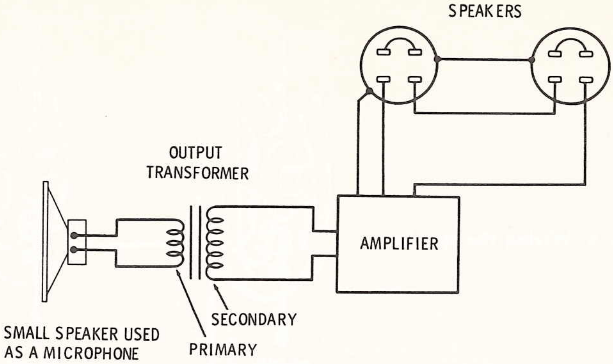


Fig. 3-7. Practical distortion test.

be run to an adjacent room, and an assistant can talk into the microphone to obtain a practical test of fidelity. For a more critical test, the speakers should be mounted in baffles or cabinets. Note that this arrangement can be applied as a one-way intercom.

In case of poor fidelity, measure the battery voltage. If the supply voltage is normal, poor fidelity can be caused by off-value resistors or capacitors. Sometimes the metal battery cases become electrically "hot" (particularly when lantern batteries are used). In such case, the amplifier operation changes when a battery case is touched. This condition can be corrected by grounding the battery cases to the copper-clad surface of the perf board. When operating normally, high-fidelity performance is provided, with the amplifier developing only 0.1% distortion. In troublesome locations, ground the copper-clad surface of the perf board to a cold-water pipe.

BABY MINDER

The arrangement shown in Fig. 3-8 is a useful addition to the nursery in a home. For example, the cable can be run from the

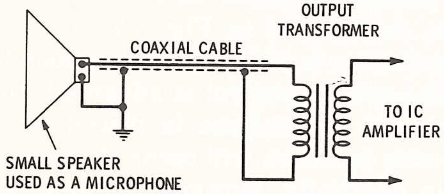


Fig. 3-8. Microphone arrangement for a baby-minder circuit.

nursery to the living room or dining room, so that parents will be alerted if baby starts to cry. It is generally necessary to use coaxial cable, particularly on longer runs, to avoid excessive hum and noise pickup. Since a coaxial cable has low impedance, best response is obtained by driving the cable from the low-impedance voice coil. In turn, the output transformer is connected at the amplifier end of the cable; therefore, a good impedance match is provided between the cable and the amplifier. The braid of the coax cable should be grounded to a water pipe to eliminate hum and noise pickup.

CHAPTER 4

A-M TUNER FOR AN IC AMPLIFIER

This project incorporates the foregoing IC preamplifier (Fig. 3-1) with a high-fidelity a-m tuner. The completed project is illustrated in Fig. 4-1. When connected to a roof antenna, this a-m tuner provides earphone-level output from a-m broadcast stations. If the output from the tuner is used to drive the IC preamplifier, satisfactory speaker volume will be obtained from local stations. Note that in case this arrangement is used in a remote area, the antenna must be elevated to a substantial height in order to intercept sufficient signal strength for speaker operation.

CIRCUIT DESCRIPTION

Observe the configuration shown in Fig. 4-2. This tuner is of the single-circuit variety with a semiconductor diode detector. Two antenna-input terminals are provided. It is advisable to connect a long antenna to tap onto the coil in order to obtain improved selectivity and minimum disturbance over the tuning range. On the other hand, in some locations it is helpful to connect a short antenna to the end of the coil. Note that the slug in the coil is a calibrating adjustment. An adequate ground connection is essential; a cold-water pipe provides efficient operation.

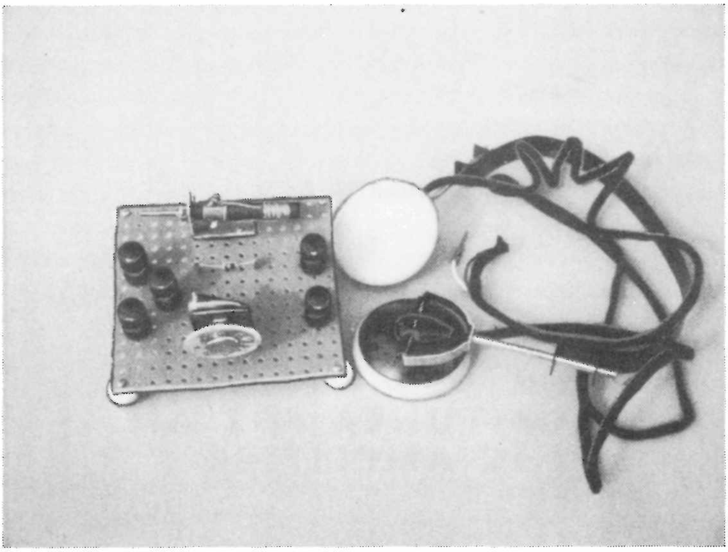


Fig. 4-1. Completed a-m tuner project.

PARTS LAYOUT

All the components in the parts list of Table 4-1 are standard, and equivalent substitutions will provide the same performance from a practical viewpoint. The ferrite antenna coil is supplied with a mounting bracket. You can use some pliers to bend this bracket into an "L" shape for convenient mounting on the perf board. Two machine screws are used to secure the bracket to the board. Conventional numbering of the coil terminals is shown in Fig. 4-3; these numbers are referred to again in the wiring diagram.

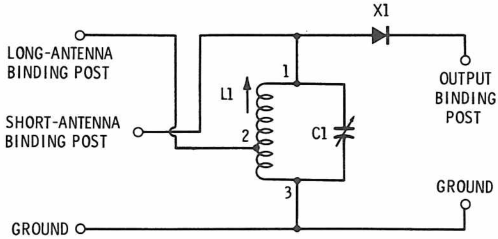


Fig. 4-2. Configuration of the a-m tuner.

Table 4-1. Parts List for A-M Tuner

Item	Description
C1	Tuning capacitor, 13-365 picofarad, single gang miniature
L1	Ferrite antenna coil
X1	Detector diode, 1N60
Circuit-board kit	Calectro J4-660 or equivalent
Binding posts	Archer 5-way (5)
Headphones	2000-ohms impedance

A short "antenna wire" is provided with the ferrite antenna coil. Loosen the end of this wire from its plastic holder and uncoil the wire. Sometimes this short "antenna" can be used, although you are not likely to be in the immediate vicinity of an a-m broadcast station. Therefore, a roof antenna must be

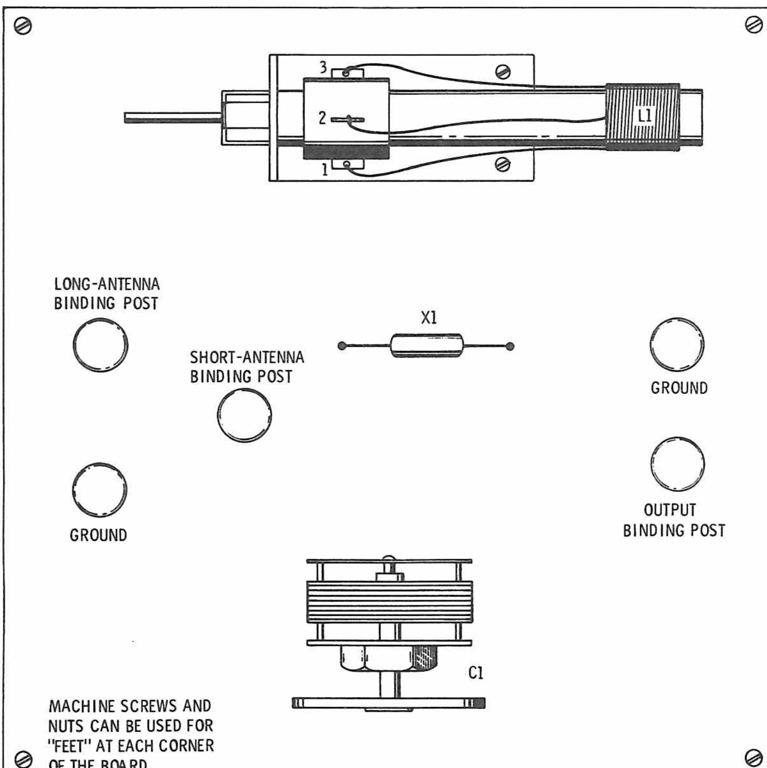


Fig. 4-3. Parts layout.

utilized in most locations. If you plan to use a roof antenna, clip the short "antenna wire" from its terminal on the coil.

Note that four rubber feet and machine screws are provided with the circuit-board kit. A foot should be mounted at each corner of the board, as seen in Fig. 4-1. Push-in terminals are also provided in the kit. Insert one pair of push-in terminals at suitable points on the board for mounting C1. The tuning capacitor will be supported by soldering its terminal lugs to the push-in terminals. Also, insert a pair of push-in terminals at suitable points on the board for mounting diode X1. If the perf-board holes are too small to pass the shanks of the binding posts, enlarge the holes with a drill.

WIRING THE CIRCUIT BOARD

Fig. 4-4 shows the pictorial wiring diagram for the a-m tuner. Solder the terminal lugs of C1 to the push-in terminals on the top side. Do not insert the diode at this time. The rest of the connections are made on the underside of the board, with the exception of coil connections. That is, the ground leads are passed through perf-board holes and connected to terminal 3 of the coil. Similarly, the long-antenna binding post is connected to terminal 2, and X1 is connected to terminal 1 by passing the leads through perf-board holes and making connections to the coil terminals.

After the wiring is completed underneath the circuit board, the diode is connected (either polarity) to its push-in terminals. Before soldering a diode lead to a push-in terminal, attach an alligator clip between the diode and the terminal. The clip acts as a heat sink and prevents excessive heat from running up the lead into the diode. Excessive heat will damage a semiconductor diode. If you do not have an alligator clip handy, you can grasp the lead between the diode and the terminal with a pair of thin-nose pliers while the soldering is being done. It is advisable to check your connections carefully. If no wiring errors have been made, the tuner is ready for test.

TESTING THE A-M RADIO TUNER

Connect a pair of headphones to the output terminals. Best reception will be obtained if you use 2000-ohm phones. A roof-

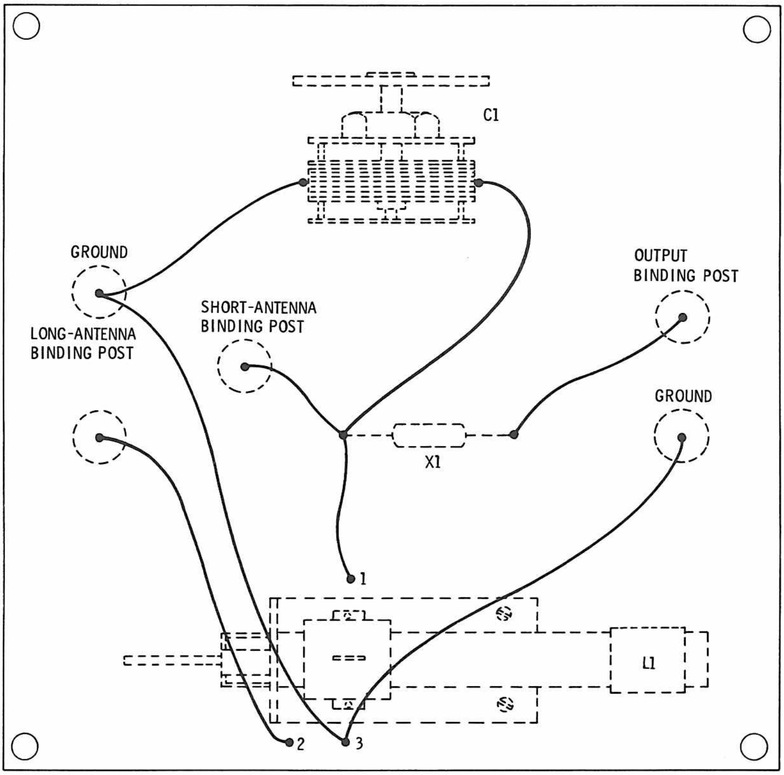


Fig. 4-4. Wiring diagram.

mounted tv antenna can be connected to either the short-antenna or the long-antenna binding post for a preliminary test, as shown in Fig. 4-5. It is usually important to use a good ground connection; run a ground wire from a cold-water pipe to the ground binding post of the circuit board. Now, if you turn the control disc on the variable capacitor, you will probably hear at least one and probably several radio stations. However, if you are far away from a-m broadcast stations, you may need to erect an elevated radio antenna. Remember that antenna height affects signal strength.

In case you seem to have a "dead" tuner, recheck your wiring connections. Cold solder joints commonly cause trouble, even though the wires run to correct terminals. In remote areas, it is possible that a seemingly "dead" tuner will become operative after sunset. To repeat an important point, the most effective

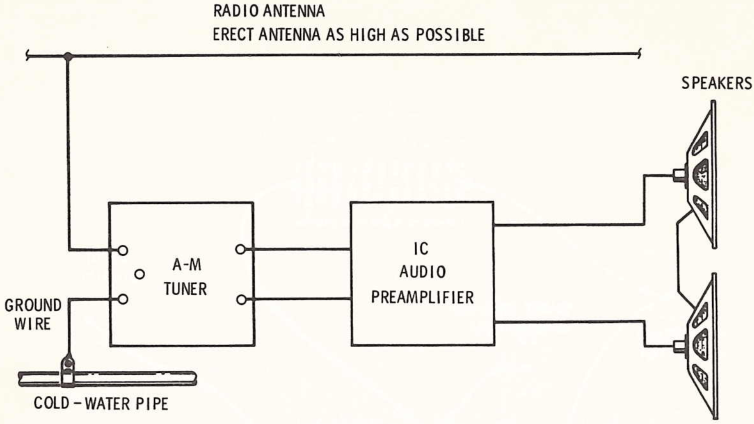


Fig. 4-5. Amplifying the tuner signal.

way to improve reception is to increase the height of your antenna. After the tuner is operating satisfactorily with a particular antenna, check the tracking of the tuning dial. If the frequencies marked on the dial do not agree with the station frequencies, turn the slug in the coil as required to make the dial indicate correctly.

SPEAKER OPERATION

Stations that provide a comfortable listening level in the headphones can be amplified for operation of a speaker (Fig. 4-5). The sound quality is normally good, inasmuch as the a-m tuner is practically distortionless. However, if the volume control of the IC amplifier is advanced too far, the sound quality will be poor. That is, the volume should not be turned past the point at which distortion becomes noticeable. Of course, when the receiver is tuned to a weak station, it may be necessary to advance the volume control to maximum in order to obtain adequate output from the speaker. Under this condition, the sound quality will be good because the amplifier is not being overloaded. Note that the speaker frequency characteristic will be poor unless the speaker is mounted in a baffle or cabinet.

CHAPTER 5

SIGNAL TRACING

This project supplements the foregoing IC preamplifier for signal-tracing in radio-frequency or audio-frequency circuits. Other applications are also provided, as explained subsequently. Suitable probes are required. The audio signal-tracing probe depicted in Fig. 5-1 is very simple. It consists of a 0.05-microfarad capacitor connected in series with about two feet of coaxial cable. The capacitor should be rated for 600-volt operation. RG-59/U cable is satisfactory. The output from the cable is fed to the IC preamplifier. When an audio signal is applied to the probe and the volume control in the amplifier is suitably advanced, the audio tone will be heard from the speakers.

RF SIGNAL-TRACING PROBE

Rf signal-tracing procedures require the use of a demodulator probe. Demodulator probes, such as illustrated in Fig. 5-2, are available commercially and may be easily constructed by the experimenter. A typical circuit for a demodulator probe is shown in Fig. 5-3. Output from the cable is fed to the IC preamplifier. In turn, when an amplitude-modulated rf signal is applied to the probe, the audio modulation tone will be reproduced by the speaker. This signal-tracing arrangement is comparatively sensitive and can be used to troubleshoot radio and television receivers. The rf probe is applied in the signal channel from the antenna to the detector. From the detector to the

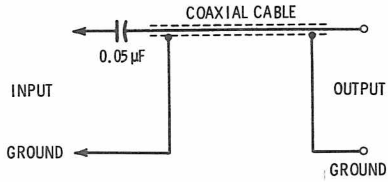


Fig. 5-1. Audio signal-tracing probe.

output of the receiver, an audio signal-tracing probe should be utilized.

In signal-tracing procedures, we move the probe stage-by-stage from the grid or plate of one tube to the next (or from

Fig. 5-2. Demodulator probe.

the base or collector of one transistor to the next) to find where the signal stops. If a stage is defective and weakens the signal instead of amplifying it, this fact also becomes apparent while signal tracing. That is, the signal strength will decrease

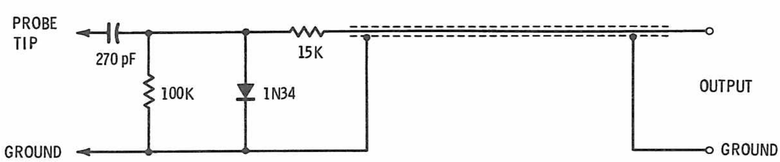


Fig. 5-3. Demodulator-probe circuit.

when the probe is moved from the grid to the plate of a tube (or from the base to the collector of a transistor). As we proceed through the signal channel of a receiver, the volume control of the IC preamplifier must be adjusted as required to prevent overload, or conversely, to provide adequate speaker output. *Note that a demodulator probe has no response to an fm signal.*

Since a probe tends to load high-impedance circuits and to detune high-frequency resonant circuits, we must be on guard to avoid jumping to false conclusions in some situations. For example, if we are signal-tracing a radio receiver and find a weak signal at the grid of a tube, it would be premature to conclude that the stage is defective. Instead, we will check the signal at the plate of the same tube. In case normal output is observed at the plate, we will conclude that the difficulty at the grid point was caused by circuit loading. In general, a signal-tracing probe is a useful indicator but should not be used to measure stage gain or loss.

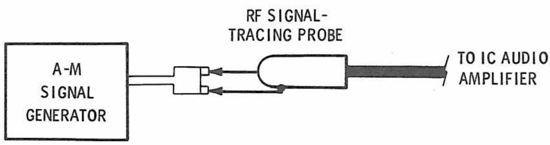


Fig. 5-4. Measuring the output of an a-m signal generator.

An rf signal tracer is useful in various other applications. For example, it can be used to measure the output from an a-m signal generator, as depicted in Fig. 5-4. Again, the signal tracer is useful to monitor the output from a CB transmitter, as shown in Fig. 5-5. An automobile whip antenna operates satisfactorily in this application, or a short rod antenna can be improvised. This application is useful to make comparative tests of CB transmitters, to check transmitter adjustments, and to evaluate transmitting antenna adjustments.

The signal tracer is also used to check neutralizing adjustments in an a-m phone transmitter, as depicted in Fig. 5-6. The general procedure is as follows:

1. To neutralize a triode rf amplifier stage, first turn off the plate power to the tube.
2. Connect a loop of wire to the signal-tracing probe.

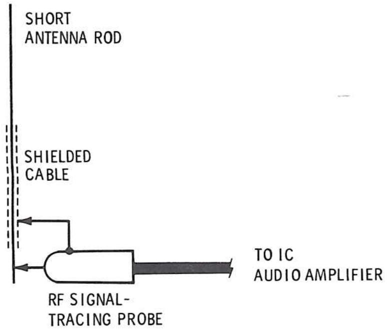


Fig. 5-5. Monitoring the output from a CB transmitter.

3. Modulate the transmitter with a steady tone signal, as from an audio oscillator. Approximately 100% modulation is desirable in this test.
4. Make sure that grid current is flowing in the triode as indicated by the grid-current meter in the transmitter.
5. Turn the neutralizing capacitor either to minimum or to maximum. This setting throws the stage completely out of neutralization.
6. Tune the plate tank circuit for maximum sound output from the signal tracer.
7. Finally, adjust the neutralizing capacitor for minimum sound output from the signal tracer. The stage is then neutralized.

Beginners should be warned that the dc voltages in a-m radio transmitters are extremely dangerous. Great care must be

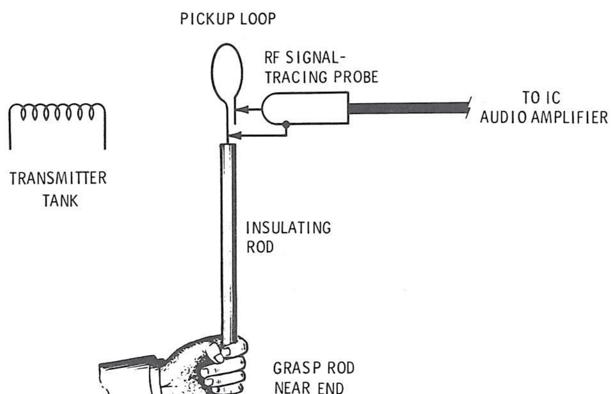


Fig. 5-6. Neutralizing an rf stage in an a-m phone transmitter.

taken to avoid shocks when working on a transmitter. One advantage of the signal tracer is that the pickup loop can be positioned at a substantial distance from the tank and still provide a useful output from the signal tracer.

RELATIVE FIELD-STRENGTH METER

A relative field-strength meter is a receiver arrangement that provides meter indication of the output signal strength. A 0–.5 milliammeter is utilized in the arrangement depicted in Fig. 5-7. Thus, both audible and metered indications are provided. The meter is connected across the speaker with a 1N34 diode as shown in Fig. 5-7. Any 0.5-mA dc meter is

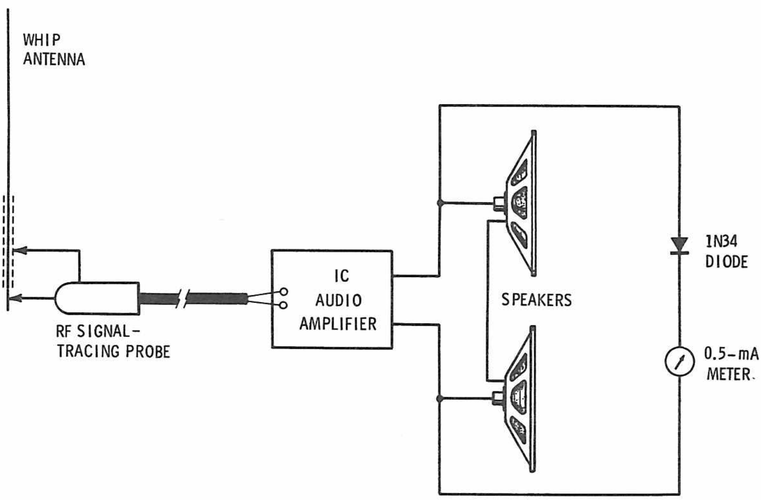


Fig. 5-7. Relative field-strength meter arrangement.

suitable. Note that the diode must be polarized correctly, so that the pointer deflects up-scale. As the volume control of the IC amplifier is turned up, the sound volume from the speaker increases, and the meter indicates higher up on the scale. It is usually desirable to mount the meter in the same cabinet as the speaker.

In operation, we set the volume control to a convenient reference level such as half-scale deflection on the meter. Then as the field strength varies, the pointer will move up or down on the scale. Of course, the sound output from the speaker will also

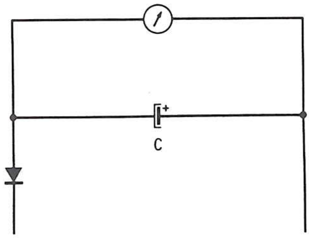


Fig. 5-8. Capacitor providing meter damping.

increase or decrease. A relative field-strength meter is very useful to monitor the output from a CB transmitter or ham transmitter while transmitter or antenna adjustments are being made. The meter indication provides a more accurate evaluation of field strength than does the speaker output. As noted previously, the transmitter must be amplitude-modulated by a steady tone when using the arrangement of Fig. 5-7.

You will notice that the pointer jumps up and down rapidly on the meter scale when the relative field-strength meter is responding to a voice or a musical transmission. However, a simple elaboration of the basic meter circuit will dampen the meter response so that the average indicated value is stabilized. This is done as depicted in Fig. 5-8. An electrolytic capacitor is connected across the meter terminals to filter the diode output voltage. Note that the capacitor must be polarized as shown. Any low-voltage electrolytic capacitor of 5 microfarads or greater will be suitable.

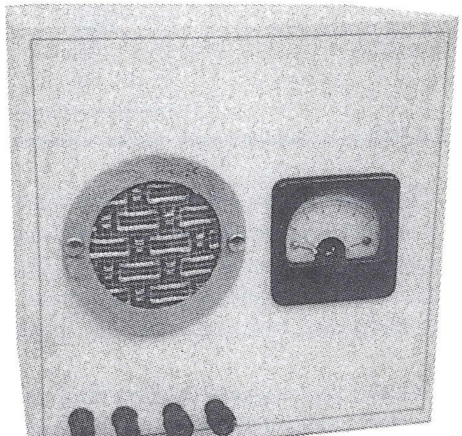


Fig. 5-9. Experimental relative field-strength meter.

For experimental work, you will probably prefer to mount the meter, rectifier, capacitor, and speaker in a corrugated paper or cardboard box, as exemplified in Fig. 5-9. The IC audio amplifier can also be placed in the same box, thereby providing a self-contained portable unit that is convenient for field testing. In this application, a small speaker is preferable. An automobile antenna can be used to provide signal input to the relative field-strength meter. Or, if you wish to walk about with the unit, a short whip antenna can be mounted on top of the box.

CHAPTER 6

AUDIO-OSCILLATOR APPLICATIONS

This group of projects exploits feedback circuits with the foregoing IC audio preamplifier in several useful audio-oscillator applications. These feedback circuits operate with various control devices and require no modification of the preamplifier.

CODE-PRACTICE OSCILLATOR

The code-practice oscillator project utilizes an RC voltage-divider feedback circuit with a key, as illustrated in Fig. 6-1. It comprises four components: 1-megohm resistor, 2200-ohm resistor, 220-pF capacitor, and a key. Fig. 6-2 shows the configuration that is employed. Note that three leads are provided in Fig. 6-1. Two of the leads are clipped to the input terminals of the preamplifier. The third lead is clipped to the "high" terminal of the speaker. It is important to construct the feedback circuit properly; otherwise, "feedthrough" will occur. Note that the 1-meg resistor connects directly at the clip to the "high" terminal of the speaker. This isolates the keying arrangement from the amplifier output system so that proper control action is obtained.

Resistor values are not critical; half-watt, 10% resistors were used. Although a Brach key was employed, any equivalent key will be satisfactory. Note that the 220-pF capacitor and the 2200-ohm resistor are supported by the key binding posts.

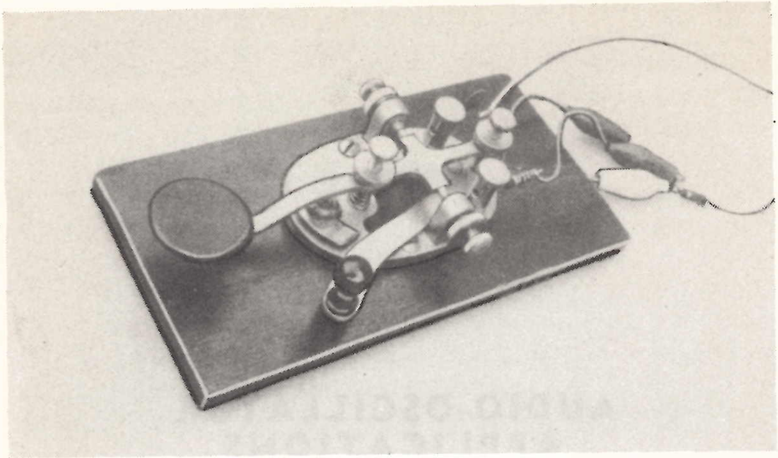


Fig. 6-1. Key with RC voltage-divider arrangement.

However, the 1-meg resistor is soldered to the clip that connects to the speaker. You will find it convenient to mount the key on a baseboard, as seen in Fig. 6-1.

To test the code-practice oscillator, connect the key assembly to the IC audio preamplifier, as shown in Fig. 6-2. Turn the volume control approximately halfway up and depress the key. If the feedback circuit is operating normally, you will hear a loud audio tone from the speakers. Next, adjust the setting of the volume control and observe how the audio oscillating frequency changes. That is, the volume control of the amplifier operates as a frequency control in this application. If you wish to reduce the sound volume, use less supply voltage to the IC preamp.

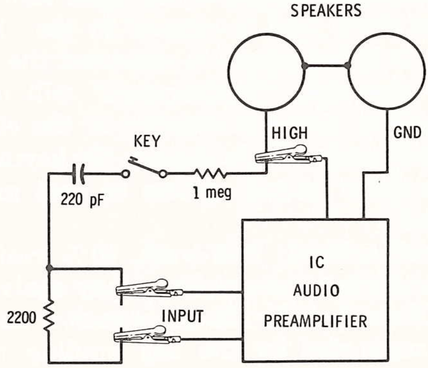
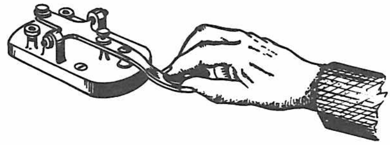


Fig. 6-2. Code-practice oscillator configuration.

Fig. 6-3. Standard hand position.



USING THE CODE-PRACTICE OSCILLATOR

Beginners tend to hold the key too tightly. It is good practice to let the hand rest lightly on the key, as depicted in Fig. 6-3. Spring tension should be adjusted to suit the operator, and the key contacts should be spaced fairly closely. A wrist motion is recommended rather than an arm motion. Your fingers should remain on the key knob at all times while operating. Try to remain relaxed—if the operator becomes nervous or "up tight," the clarity of his code transmission will be impaired. The best "fist" comes through like an automatic code transmitter.

Fig. 6-4 shows the Continental, or International Morse code used in radiocommunication. The length of a dash is equal to three dots. It is advisable to enlist the aid of a friend in learning the code. Remember that although it is easier to send code than to receive it, you will be unable to obtain an amateur radio license unless you are proficient in code reception.

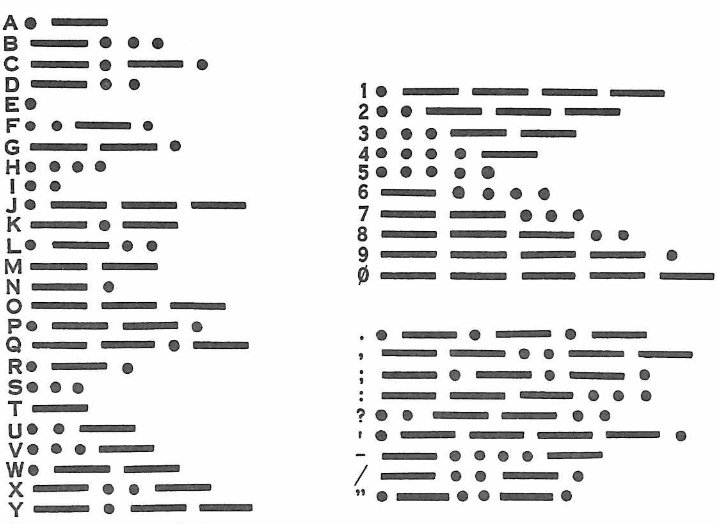


Fig. 6-4. The Continental or International Morse code.

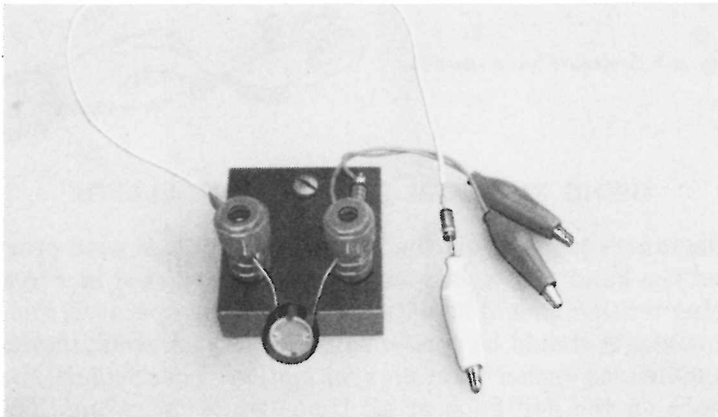


Fig. 6-5. Light-dependent audio alarm.

LIGHT-DEPENDENT AUDIO ALARM

This light-dependent audio alarm project utilizes the same basic oscillator arrangement as in the foregoing code-practice oscillator. Fig. 6-5 shows the appearance of the completed project without the preamplifier. It employs a cadmium-sulfide photocell, seen in the foreground. The photocell is connected in series with a 1-meg resistor, a 220-pF capacitor, and a 2200-ohm resistor. Thus, the photocell operates in an RC voltage-divider feedback network when used with the IC audio preamplifier. When the photocell is exposed to light, the speakers produce a loud audio tone. On the other hand, when the photocell is in darkness there is no sound output from the speakers. The entire configuration is illustrated in Fig. 6-6.

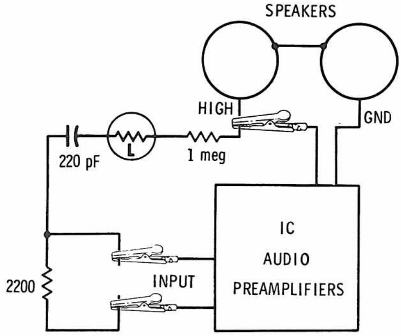
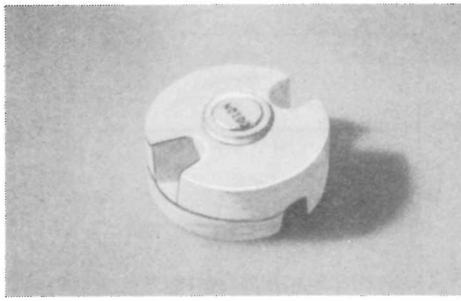


Fig. 6-6. Configuration of the light-dependent audio alarm.

Fig. 6-7. Heat sensor.



An Archer cadmium-sulfide photocell is suitable for use in this project. It is mounted in a pair of binding posts with the binding posts mounted on a wood or plastic base. As in the case of the code-practice oscillator, the binding posts are also utilized to secure the 2200-ohm resistor and the 220-pF capacitor. The 1-meg resistor is soldered to the clip that connects to the speaker terminal. Since the resistance of the photocell varies from 100 ohms in bright light to 0.5 megohm in complete darkness, it operates essentially as a switch in the feedback circuit.

This light-dependent audio alarm serves as an effective burglar alarm. Even the illumination provided by a flashlight will operate the alarm. Similarly, this unit operates as an efficient fire alarm. For example, if the photocell is located in an attic, storeroom, or garage, the alarm will sound in case the photocell is illuminated by fire. If a combination light-and-heat alarm is desired, the photocell may be paralleled with a heat sensor. An SD-24 heat sensor (Fig. 6-7), or equivalent, is suitable. The heat sensor will close the feedback circuit at a temperature of approximately 190° F, thereby sounding an audio alarm.

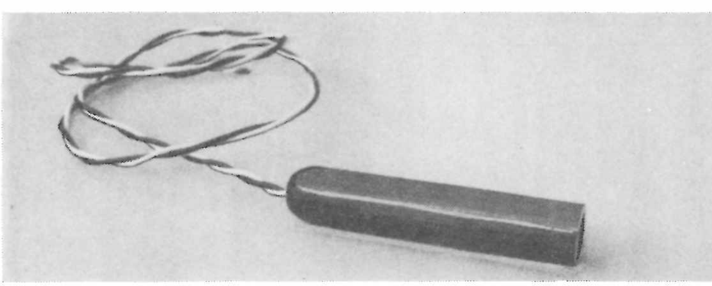


Fig. 6-8. Directional light sensor.

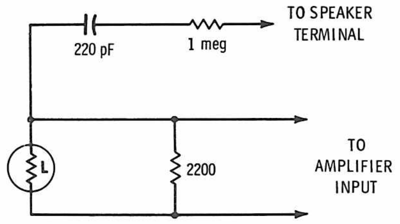


Fig. 6-9. Feedback circuit for a darkness-responsive audio alarm.

In some applications, we wish the alarm to sound only when light appears from a certain direction. This is accomplished by placing the photocell at the end of a plastic tube, as illustrated in Fig. 6-8. A black tube is preferable to prevent response to off-axis light beams. If greater directivity is desired, a longer tube may be used. Be sure to seal off the end of the tube behind the photocell to avoid light leaks.

DARKNESS-RESPONSIVE AUDIO ALARM

In some applications, it is desired to have the alarm triggered only in darkness. For example, the alarm can be triggered as a person breaks a light beam. Thus, a light beam may be directed across a doorway in a store or office. The same components are used as in the foregoing project. However, the feedback circuit is slightly different, as shown in Fig. 6-9. That is, the photocell is connected across the 2200-ohm resistor instead of being in series with the resistor.

CHAPTER 7

INTEGRATED-CIRCUIT AUDIO AMPLIFIER

This project provides an integrated-circuit audio amplifier with a 1-watt output. The completed project is illustrated in Fig. 7-1. However, it can be driven by the IC preamplifier previously described. Two of the output amplifiers can be used in a stereo system, for example, to obtain a total output of 2 watts.

CIRCUIT DESCRIPTION

A Motorola HEP C6008 integrated circuit is utilized in this project. The IC is ¼ inch square and has six terminals. Although we are not concerned practically with the internal configuration of the IC, it is interesting to note the internal circuitry shown in Fig. 7-2. An IC socket is not used in this project; therefore, the solder connections are made directly to the IC terminals.

Fig. 7-3 shows the configuration of the audio amplifier. An off-on switch was not included, as it is easy to snap the battery clip off when the amplifier is not in use. However, if you prefer, you can use a volume control with an off-on switch to disconnect the battery. In any case, since the IC draws approximately 5 mA, the battery should not be left connected to the amplifier when it is not being used. The metal housing of the potentiometer should be grounded to the negative supply-voltage bus to avoid the possibility of unstable operation and/or

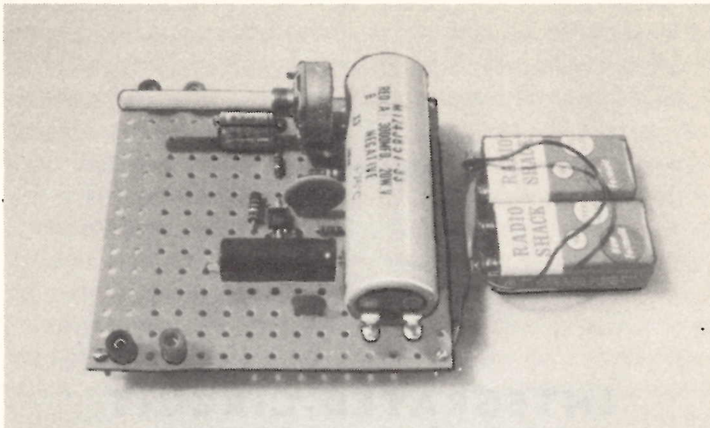


Fig. 7-1. Completed integrated-circuit audio amplifier project.

hum pickup. In this project, all connections are made on the bottom of the perf board.

Component values are indicated in Fig. 7-3, and a parts list is provided in Table 7-1. This amplifier employs a 16-ohm speaker or two 8-ohm speakers connected in series. Since no output transformer is utilized, optimum fidelity is obtained.

PARTS LAYOUT

Before proceeding to mount the parts on the perf board, check all component values carefully. Fig. 7-4 shows the parts

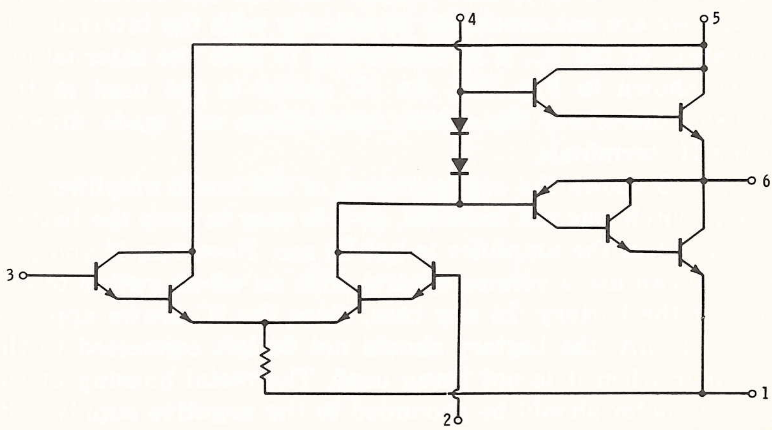


Fig. 7-2. Internal circuitry of a C6008 IC.

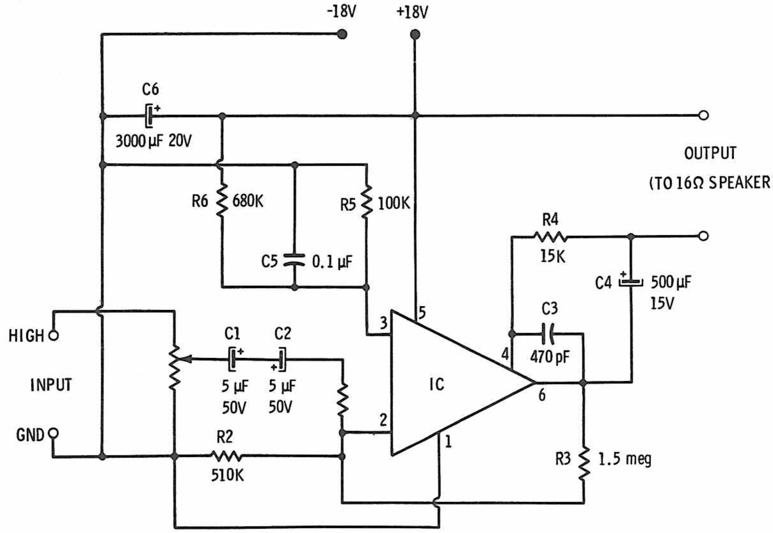


Fig. 7-3. IC audio amplifier configuration.

layout from the top of the board. Fig. 7-5 depicts the wiring on the under side of the board. Note that the IC is mounted in the center of the board. Six holes are drilled through the board to pass the IC terminal lugs which are soldered into the

Table 7-1. Parts List for IC Audio Amplifier

Item	Description
C1, C2	Capacitors, 5 microfarad, 50 volt, electrolytic
C3	Capacitor, 470 picofarad, ceramic disc
C4	Capacitor, 500 microfarad, 15 volt, electrolytic
C5	Capacitor, 0.1 microfarad, ceramic disc
C6	Capacitor, 3000 microfarad, 20 volt, electrolytic
R1	Potentiometer, 100,000 ohms, 1/2 watt, linear taper
R2	Resistor, 510,000 ohm, 1/2 watt, 10%
R3	Resistor, 1.5 megohm, 1/2 watt, 10%
R4	Resistor, 15,000 ohm, 1/2 watt, 10%
R5	Resistor, 100,000 ohm, 1/2 watt, 10%
R6	Resistor, 680,000 ohm, 1/2 watt, 10%
Circuit board	Perforated circuit board
Speakers	8-ohm voice coil (2)
Batteries	9-volt (2)
Binding posts	Push-in type (4)
Battery Clips	For 9-volt battery

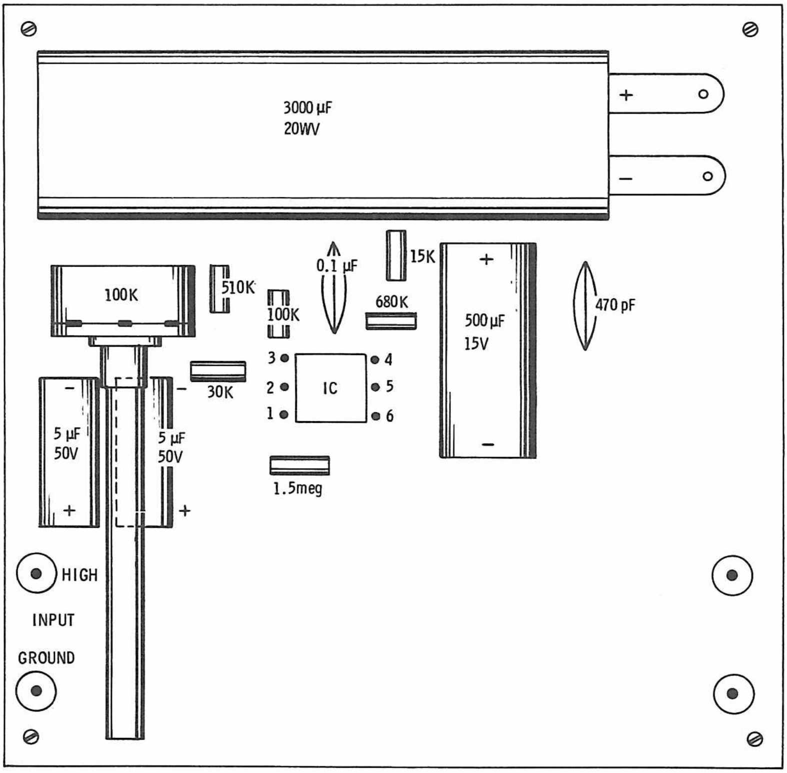


Fig. 7-4. Parts layout.

circuit on the under side of the board. Be sure to mount the IC with its ridge side toward the potentiometer.

Since the circuit board has numerous perforations, it is a simple procedure to insert the leads of capacitors and resistors through various holes. The potentiometer lugs may also be passed through holes in the board, or stiff hookup wire may be passed through and soldered to the lugs. Most of the wiring below the circuit board can be completed using the leads of the various components. A soldering gun can be used for making the majority of the connections. However, a pencil-type soldering iron should be used for this purpose. Be sure to use a heat sink as each IC terminal is soldered. For example, a small alligator clip can be attached to an IC terminal lug on the top side, while a solder connection is being made to the lug on the underside of the board.

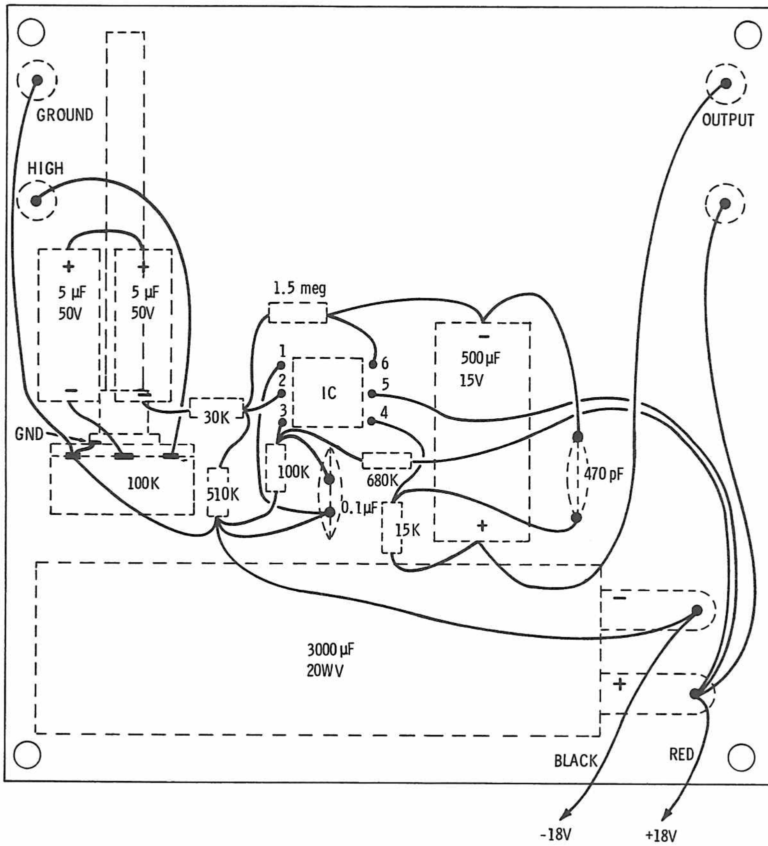


Fig. 7-5. Pictorial wiring diagram.

Since two 9-volt batteries are employed, one of the battery-snap strips must be cut to separate the positive and negative snaps. Thereby, a "jumper" can be made up to connect the batteries in series. Or, you can utilize a 12-volt and a 6-volt lantern battery connected in series to obtain longer life before replacement is required. It is very important to make sure that battery polarities are connected correctly.

TESTING THE AMPLIFIER

To test the completed amplifier, connect a 16-ohm speaker (or a pair of series-connected 8-ohm speakers) to the output posts. Fig. 6-6 shows how to connect a pair of speakers for

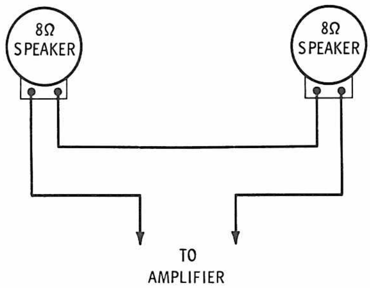


Fig. 7-6. Speaker connections.

proper phasing. Connect the batteries to the amplifier. Now, if you turn the volume control to maximum, you will normally hear a weak *rushing* sound from the speakers. This is thermal noise developed by the amplifier. Next, turn the volume control to zero and touch your finger to the input (high) post. Advance the volume control, and you will probably hear a 60-Hz hum note from the speakers. In case trouble is experienced, check the points discussed in Chapter 3.

After the amplifier has passed its initial tests, a practical distortion test can be made by connecting a small speaker with an output transformer to the input terminals of the amplifier. When the volume control is advanced, the speakers will "howl" due to acoustice feedback unless the microphone is located at a suitable distance from the speakers. An assistant can talk into the "microphone" from an adjacent room to obtain a practical test of fidelity. In case of distortion, check the points noted in Chapter 3. This amplifier can be used in a baby-minder application although its sensitivity is less than that of the preamplifier. Similarly, this amplifier can be used as a signal tracer or a field-strength indicator, or as an amplifier for the a-m tuner previously discussed. However, its sensitivity in these applications is less than that provided by the preamplifier.

For maximum amplifier sensitivity in weak-signal situations, we can use the preamplifier to drive the output amplifier. It is quite possible for instability to occur in this high-gain system, unless the ground terminal of the preamp is connected to a cold-water pipe. This will normally stabilize the system for any settings of the gain controls. You will note that when the volume control of the output amplifier is turned to maximum, a fairly loud rushing sound is heard from the speakers. This is due to amplification of thermal noise from both the preamplifier

and the output amplifier. Note also that the level of the thermal noise varies as the volume control of the preamplifier is turned. This change in noise level is caused by the thermal noise of the 100,000-ohm resistance in the preamp volume control.

TYPICAL APPLICATIONS

To obtain maximum performance from the a-m tuner previously described, the output from the tuner may be passed through the preamp and finally through the output amplifier. Similarly, a high-gain signal tracer can be obtained by using the demodulator probe to drive the preamp which in turn drives the output amplifier. Low-level phono cartridges operate the speakers satisfactorily with this audio system. Similarly, low-level microphones can be utilized. The maximum available gain of the system is 140 dB.

CHAPTER 8

INTEGRATED-CIRCUIT A-M TUNER

This project consists of a sensitive a-m tuner, using an integrated circuit with a gain of 26 dB. The completed project is illustrated in Fig. 8-1. It responds to comparatively weak signals, and can be used with a much smaller antenna than the tuner described in Chapter 4. When used to drive the preamplifier discussed in Chapter 3, good speaker volume can be obtained on local broadcast signals. The tuner alone will provide moderate speaker output on strong signals.

CIRCUIT DESCRIPTION

A Motorola HEP C6010 integrated circuit is utilized in this project. The IC is ¼ inch long and ⅛ inch wide, and has four terminals. Its terminal arrangement is depicted in Fig. 8-2A. Although we are not concerned practically with the internal configuration of the IC, it is interesting to note the internal circuitry shown in Fig. 8-2B. An IC socket is not used in this project, therefore, solder connections are made directly to the IC terminals.

Fig. 8-3 shows the configuration of the integrated-circuit a-m tuner. An off-on switch was not included, since it is easy to snap the battery clip off when the tuner is not in use. If you prefer, however, you can add a small toggle switch to the arrangement to disconnect the battery. In any case, since the IC

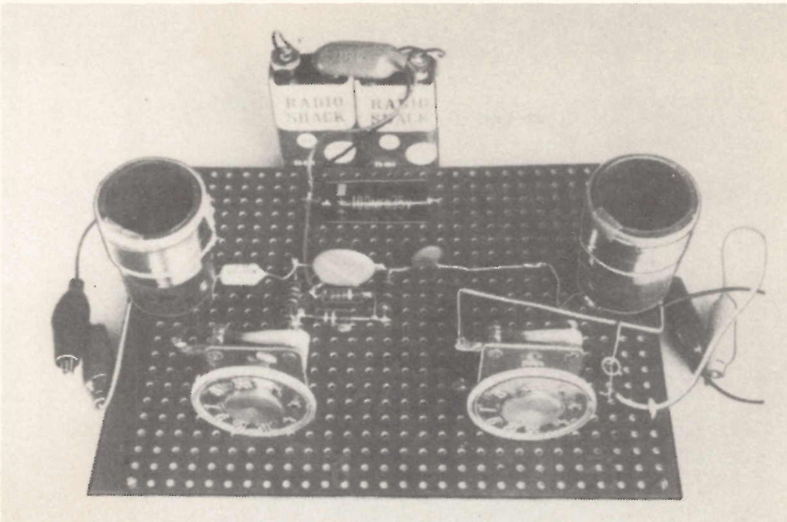
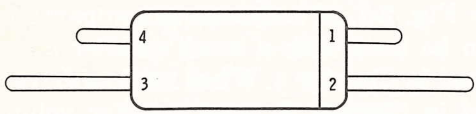
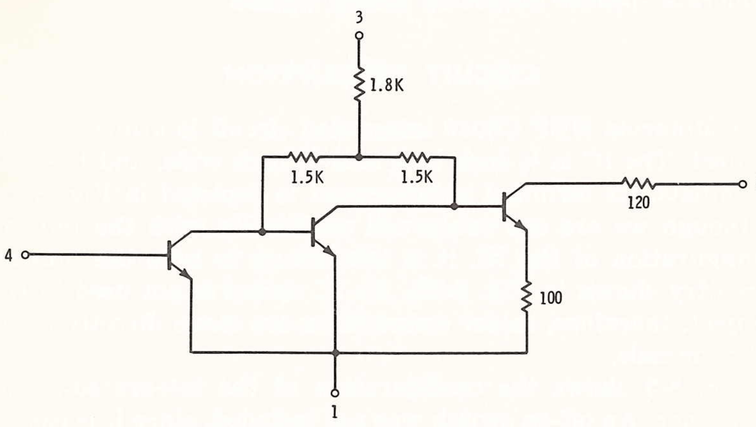


Fig. 8-1. Completed integrated-circuit a-m tuner.



(*A*) *Terminal arrangement.*



(*B*) *Internal configuration.*

Fig. 8-2. The C6010 integrated circuit.

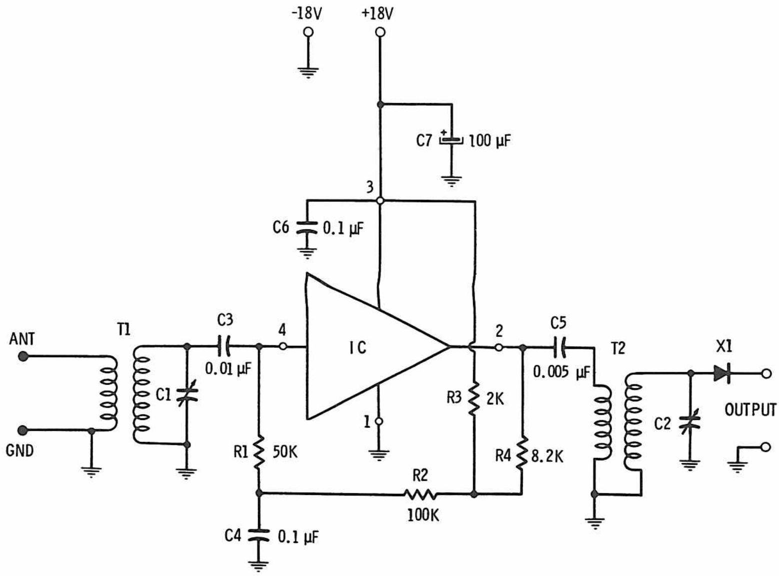


Fig. 8-3. Tuner configuration.

draws 3 mA, approximately, the battery should not be left connected to the tuner when it is not being used. We observe in Fig. 8-1 that all connections are made on the top side of the perf board. The under surface of the perf board is copper-clad, and serves both as a ground plane and as partial shielding for the components.

Component values are indicated in Fig. 8-3, and a parts list is provided in Table 8-1. Earphones are not included in the list; if you wish to use earphones with the tuner, they should have a resistance of 2000 ohms. For example, Realistic 2000-ohm earphones will provide good performance.

PARTS LAYOUT

Before proceeding to mount the parts on the perf board, check all component values carefully. An off-value bias resistor, for example, could impair the performance of the tuner. Fig. 8-4 shows the parts layout with a pictorial wiring diagram corresponding to Fig. 8-3. Note that the IC is mounted on top of the perf board. Observe the IC terminal numbers in Fig. 8-4. These correspond to the terminal numbers shown in Fig. 8-2.

Table 8-1. Parts List for IC A-M Tuner

Item	Description
C1, C2	Capacitors, 365-picofarad variable
C3	Capacitor, 0.01 microfarad
C4	Capacitor, 0.1 microfarad
C5	Capacitor, 100 microfarad, 25 volt, electrolytic
C6	Capacitor, 0.1 mcirofarad
C7	Capacitor, 0.005 microfarad
IC	Integrated circuit, Motorola HEP C6010.
R1	Resistor, 50,000 ohms, 1/2 watt, 10%
R2	Resistor, 100,000 ohms, 1/2 watt, 10%
R3	Resistor, 2000 ohms, 1/2 watt, 10%
R4	Resistor, 8200 ohms, 1/2 watt, 10%
Circuit board	Perforated board, copper-clad
Batteries	9-volt (2)
Test cords	With insulated clips (4)
Battery clips	For 9-volt battery (2)
T1, T2	Coils, TRF, 540-1750 kHz
X1	Diode, germanium, Motorola HEP 134.

Be careful not to reverse the IC end-for-end when mounting it on the perf board.

Since the circuit board has numerous perforations, it is a simple procedure to insert the ground leads of capacitors and resistors through the various holes. The leads are clipped below the board and soldered to the copper-clad surface. If a pencil-type soldering iron does not produce enough heat to solder to the copper sheet, use an ordinary soldering gun in this part of the procedure. Note that electrolytic capacitors are polarized, and it is essential to observe correct polarity. In general, connections to the IC terminals should be made last. Also, it is very important to use a pair of tweezers (or a small alligator clip) as a heat sink as each IC terminal is being soldered. Apply the heat sink between the solder point on the terminal and the body of the IC. Allow the joint to cool before removing the heat sink.

Note that the TRF coils are provided with mounting brackets. These are secured to the perf board with small machine screws. Since two 9-volt batteries are utilized, one of the battery-snap clips must be cut to separate the positive and negative snaps. Thereby, a "jumper" can be made up to connect the two 9-volt batteries in series. It is very important to make sure that batteries are connected in correct polarity.

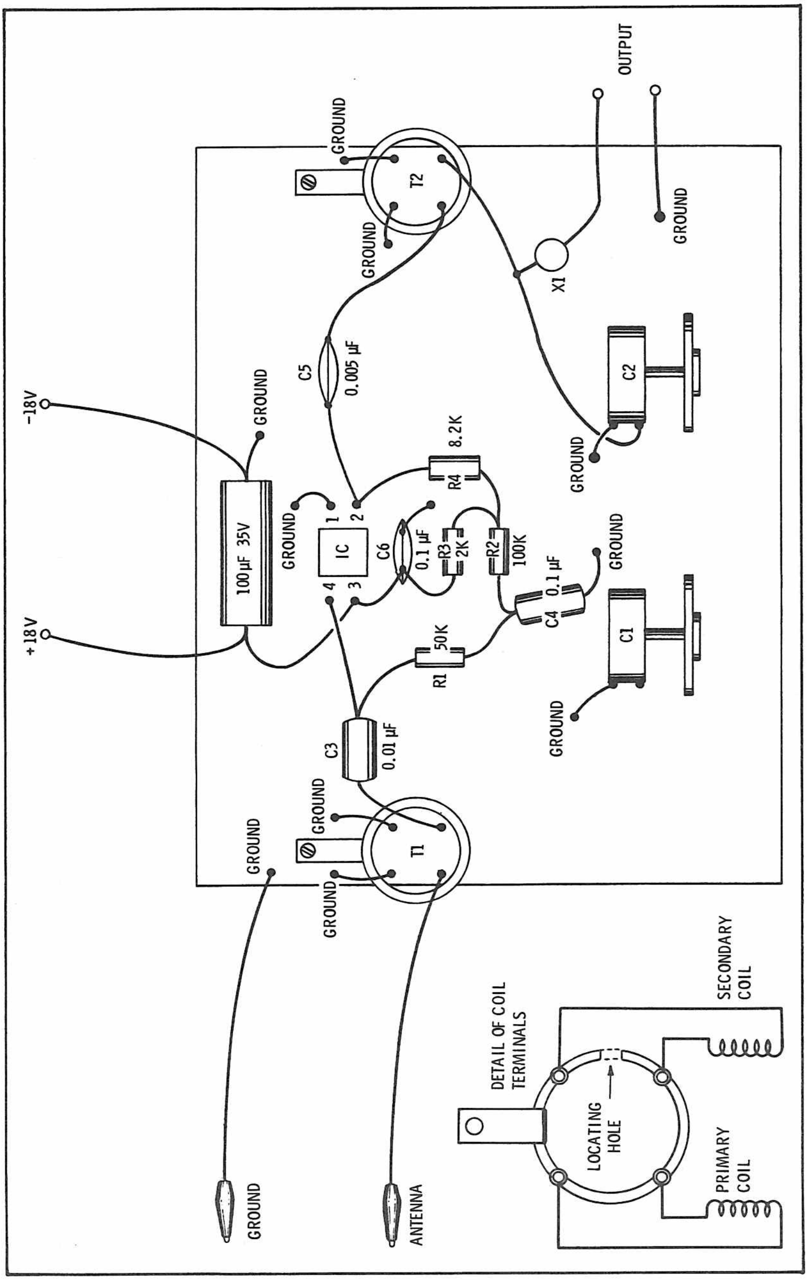


Fig. 8-4. Parts layout and wiring.

TESTING THE IC TUNER

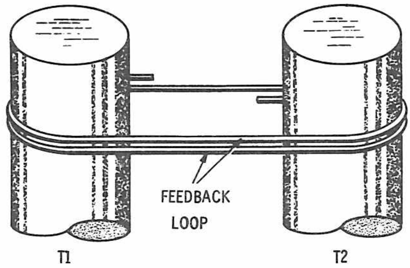
To test the completed tuner, connect the output leads to the input of the preamplifier. Connect the batteries to the tuner. Connect a short antenna to the antenna-input clip. If the ground clip is connected to a wire running to a cold-water pipe, stronger signals will result. Turn up the volume control on the preamp. Adjust the tuning condensers on the tuner, keeping the dials at approximately the same frequency indications. Under normal conditions, you will hear several broadcast stations at good speaker volume. If weak or no reception is obtained, check component values and wiring connections in the tuner.

After the tuner has passed its preliminary test, you will probably note that the tuning is rather broad and that two or more stations may interfere with each other. This is particularly noticeable if you have a long antenna connected to the tuner. To obtain good selectivity, slide the primary coils on T1 and T2 up toward the top of the form. This loosens the coupling between primary and secondary, and makes the tuning more selective. In case still greater selectivity is desired, the primary coils may be slid partially off the tops of the secondary coil form. This will necessitate unwinding one turn at the top and one turn at the bottom of the primary, in order to obtain sufficient lead lengths.

You will observe that when the primary is slid partially off the secondary coil form, that the tuning becomes quite sharp. On the other hand, the output volume from the tuner decreases. Therefore, the coupling adjustments often involve a compromise between volume and selectivity. When the optimum position is found for a primary coil, it can be secured in place by a drop of household cement. Note that if you use some other antenna with the tuner, it will be desirable to try another value of coupling.

Since this IC is quite responsive to bias-voltage variation, optimum sensitivity depends on operation at correct bias. This means that the resistor values should be fairly close to the design-center values noted in the parts list. Also, since there is a fairly wide tolerance on ICs, it may be helpful to experiment with small changes in resistor values to obtain peak sensitivity. If you should find that the tuner is more sensitive when operated at reduced supply voltage, the bias voltage might be

Fig. 8-5. Adding a feedback loop for regeneration.



incorrect. Of course, no attempt should be made to operate the tuner with a supply voltage greater than the rated 20 volts, or the IC is likely to be damaged. If you are operating this tuner in a weak-signal area, you will need to adjust the bias voltage for maximum sensitivity. This may require an appreciable change in the value of the 100K resistor. To find the best value, connect a 1-meg potentiometer in place of the 100K resistor. Adjust the potentiometer for maximum output when a weak signal is tuned in. Then, disconnect the potentiometer and measure the value of resistance that is required. Finally, connect this same value of fixed resistance in place of the 100K resistor, and the tuner will then operate at maximum sensitivity.

Note that this is a nonregenerative tuner. If you wish to add a regenerative feedback loop, increased sensitivity will be obtained. However, beginners should be cautioned that regeneration is somewhat tricky until experience has been gained in its use. You can easily make the tuner regenerative by providing loop coupling between T1 and T2. For example, loop a length of hookup wire once or twice around T1 and T2, as depicted in Fig. 8-5. You may now hear a "squeal" as you tune through a station signal. However, if the tuner does not oscillate, reverse the turn(s) around one of the coils. To keep the tuner from breaking into oscillation, slide the loops up on the coils until the circuit does not squeal when tuning in a station. Maximum sensitivity occurs at the point that the circuit almost oscillates.

STABILITY CONSIDERATIONS

You will find that the operating stability of the tuner depends on the supply voltage that is used, as well as a good ground connection and a suitable antenna. In other words, when a certain antenna is utilized, the tuner may oscillate when

the rated supply voltage is employed. In such a case it is advisable to operate the tuner at a reduced supply voltage, changing the bias resistor as explained previously for maximum sensitivity. If operation of the tuner is desired with a very short antenna or no antenna, and with no ground connection, it may be necessary to reduce the supply voltage considerably to avoid oscillation.

CHAPTER 9

INTEGRATED-CIRCUIT HIGH-FREQUENCY TUNER

This project provides an integrated-circuit high-frequency tuner that covers a frequency range from 9 to 27 MHz. The completed project is illustrated in Fig. 9-1. When used with a short antenna and ground connection, numerous short-wave stations can be tuned in. This tuner operates a pair of 2000-ohm earphones, or it may be used to drive the foregoing preamplifier to obtain speaker volume.

CIRCUIT DESCRIPTION

A Motorola HEP 590 integrated circuit is utilized in this project. The IC has a round case with ten terminals. Its terminal arrangement is shown in Fig. 9-2A. Although we are not primarily concerned with the internal configuration of the IC, it is interesting to note the internal circuitry shown in Fig. 9-2B. An IC socket is not utilized in this project, and solder connections are made directly to the IC terminals. A gain of 26 dB is provided by this IC.

Fig. 9-3 shows the configuration of the high-frequency tuner. An off-on switch was not included, because it is easy to snap the battery clip off when the tuner is not in use. However, if you prefer, you can install a small toggle switch to disconnect the battery. In any case, the battery should be disconnected when the tuner is not in use. Fig. 9-1 shows that all connections are

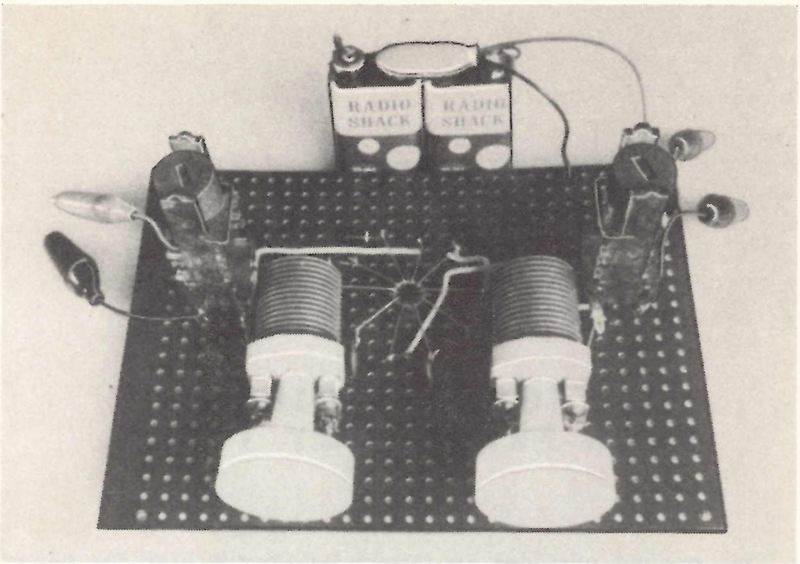
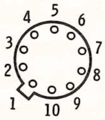
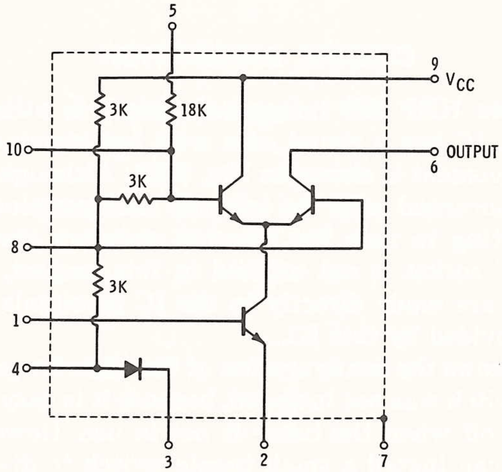


Fig. 9-1. Completed IC high-frequency tuner project.



(A) Terminal arrangement (bottom view).



(B) Internal circuitry.

Fig. 9-2. The 590 integrated circuit.

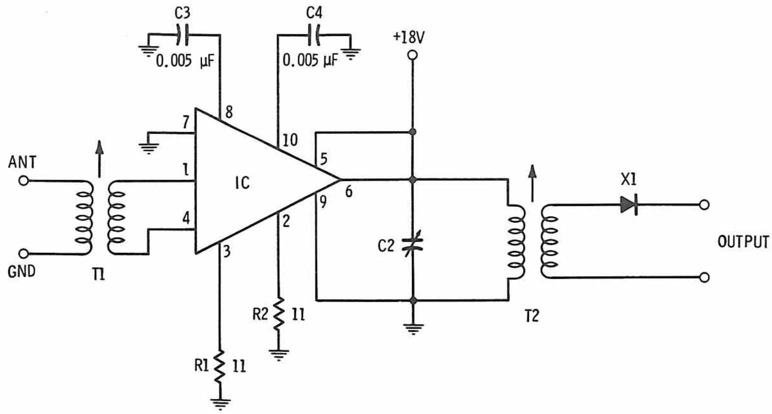


Fig. 9-3. Configuration of the IC high-frequency tuner.

made on the top side of the perf board. The under surface of the perf board is copper-clad and serves both as a ground plane and as a partial shield for the various components.

It is desirable to employ a copper-clad perf board in the project to avoid possible instability. Component values are indicated in Fig. 9-3, and a parts list is provided in Table 9-1. Note that 23-MHz bifilar transformers were used in this project. These are i-f transformers from a discarded tv receiver with a 23-MHz i-f strip. Although this type of transformer is not generally available in electronic supply stores, you can probably "dig up" an old-model tv receiver with a 23-MHz i-f. In case of difficulty, place a special order with an electronic supply store.

Table 9-1. Parts List for IC High-Frequency Tuner

Item	Description
C1, C2	Capacitors, variable, 100 picofarad,
C3, C4	Capacitors, 0.005 microfarad
IC	Motorola HEP 590
R1, R2	Resistors, 11 ohm, 1/2 watt, 10%
T1, T2	Transformers, bifilar, 23-MHz (See text)
X1	Diode, germanium, Motorola HEP 134
Circuit board	Perforated board, copper-clad
Batteries	9-volt (2)
Test cords	With insulated leads (4)
Battery clips	For 9-volt battery
Knobs	Push-on type (2) (See text)

Although the coils can be hand-wound, considerable "cut-and-try" work is generally necessary to obtain the desired tuning range.

PARTS LAYOUT

Before proceeding to mount the parts on the perf board, check all component values carefully. An off-value resistor, for example, can cause operating trouble. Fig. 9-4 shows the parts layout and pictorial wiring diagram for this project. Note that the leads of the IC are bent out at right angles from the case. The IC is mounted top-side down to facilitate connections. Observe the tab projecting from the bottom flange on the case. This tab indicates terminal lead No. 1. Terminal numbers progress clockwise as depicted in Fig. 9-4.

Tuning capacitors C1 and C2 can be readily mounted by means of heavy bus-wire stubs passed through the perf board and soldered to the copper sheet. In turn, the upper ends of the stubs can be soldered to lugs and secured to the capacitor mounting screws. Transformers T1 and T2 can be conveniently mounted by soldering appropriate terminals to the long terminal lugs on the tuning capacitors. It is permissible to remove the aluminum shield cans from the transformers, and this will facilitate subsequent slug adjustments.

Since the circuit board has numerous perforations, it is a simple procedure to insert the ground leads of capacitors and resistors through various holes. The leads are clipped below the board and soldered to the copper-clad surface. If a pencil-type soldering iron does not produce enough heat to solder to the copper sheet, use an ordinary soldering gun in this part of the procedure. Note that electrolytic capacitors are polarized, and it is essential to observe correct polarity. In general, connections to the IC leads should be made last. Also, it is very important to use a pair of thin-nose pliers (or a small alligator clip) as a heat sink as each IC lead is soldered. Apply the heat sink between the solder point on the lead and the body of the IC. Allow the joint to cool before removing the heat sink.

Knobs for the tuning capacitors may be of the push-on type. Look over some discarded tv chassis and pick out two knobs of suitable size for ¼-inch shafts. In case of difficulty, suitable knobs can probably be obtained from a large tv supply store.

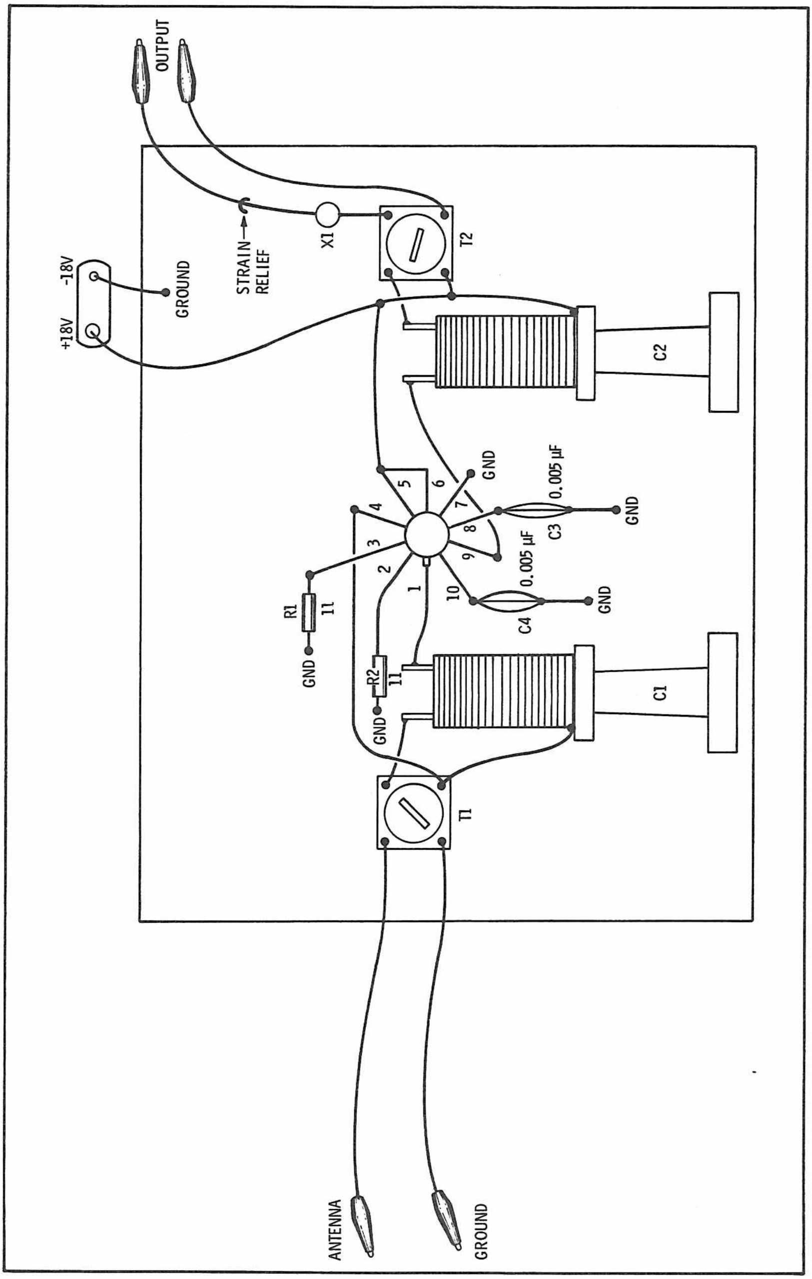


Fig. 9-4. Parts layout and wiring.

Since two 9-volt batteries are utilized, one of the battery-snap strips must be cut to separate the positive and negative snaps. In turn, a "jumper" can be made up for series connection of the batteries. It is very important to connect the batteries in correct polarity.

TESTING THE HIGH-FREQUENCY TUNER

To test the completed project, the output may be fed to the foregoing preamplifier. Connect the batteries to the tuner and a short antenna to the antenna-input clip. If the ground clip is connected to a wire running to a cold-water pipe, stronger signals will be received. Turn up the volume control of the preamplifier. Next, adjust the tuning capacitors on the hf tuner, keeping the capacitors meshed approximately the same amount. Normally, you will hear several short-wave radio stations. To tune the tuner through the 9-to-27 MHz frequency range, the tuning slugs will need to be turned as far into the coils as possible.

In case of difficulty, recheck the component values, connections, and polarities. Look for cold solder joints. In remote locations, it is possible that you might have to wait until another time of day or night to intercept short-wave signals. That is, short waves are subject to reflection from upper layers of the ionosphere, and the heights of these layers change from daylight to darkness. You will also note that a strong short-wave station often fades out and then builds up strength again. This is not the fault of the receiver but results from time variations in the ionosphere.

CONTINUOUS-WAVE RECEPTION

This is not a regenerative receiver, and the beginner is not advised to attempt its elaboration into regenerative action. However, a practical method of obtaining continuous-wave (cw) reception in this project is to utilize the bfo (beat-frequency oscillator) principle. This can be easily accomplished by means of an ordinary signal generator. The output lead from the signal generator is placed near the antenna-input lead of the receiver, and the output level of the generator is set to maximum. Then, the frequency range of the generator is set to

the band of interest, such as 9 or 10 MHz. As the variable capacitors in the tuner are progressively advanced, the frequency dial of the generator is varied back-and-forth. If the tuner is set to receive any cw signal, a "squeal" will be heard as the frequency dial of the generator is turned. The dial is set to a position that provides a convenient beat note.

INDEX

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